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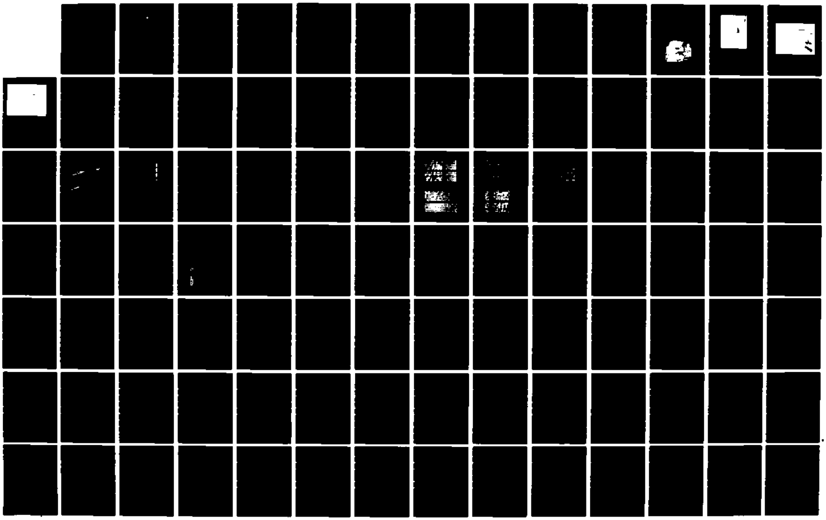

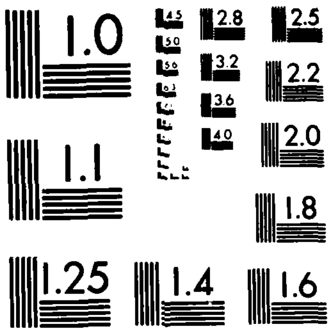

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V/STOL LOW SPEED AND TRANSITION EQUIVALENT SYSTEMS ANALYSIS

by
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DEC 1982

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A fixed base manned V/STOL handling qualities simulation was performed to investigate 1) classification criteria of attitude and rate command systems in hover and low-speed flight; 2) control system blending schemes for transition from approach dynamics to hover dynamics and vice versa, and 3) the amount of control usage. Pilot ratings and comments showed that a time response criterion discriminated well between attitude and rate systems; blending schemes for transition correlated well with earlier NASA results and; pilot's command gain had a strong effect on piloting characteristics and the amount of control usage.

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LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF SYMBOLS

CTOL	Conventional Takeoff and Landing
HUD	Head Up Display
K	High Frequency Gain, rad/sec^2/cm
K_{ss}	Steady-State Stick Sensitivity, rad/cm
K_{u_g}	Turbulence Intensity Gain, X-Direction
K_{v_g}	Turbulence Intensity Gain, Y-Direction
N_g	Random Noise Generator Output for Turbulence Model
PIO	Pilot Induced Oscillation
S	Laplace Operator, 1/sec
STOL	Short Takeoff and Landing
$1/T$	Numerator First Order Root, rad/sec
u_g	Body-Axis Turbulence Velocity, X-Direction, m/sec
v_g	Body-Axis Turbulence Velocity, Y-Direction, m/sec
VTOL	Vertical Takeoff and Landing
V/STOL	Vertical/Short Takeoff and Landing
δ_{PED}	Rudder Pedal Displacement, cm
δ_{ST}	Stick Displacement, cm
ζ	Damping Ratio
θ	Pitch Angle, rad
$\dot{\theta}$	Pitch Rate, rad/sec
λ	First Order Root, 1/sec
σ_g	Turbulence Intensity Level, Knots
ϕ	Roll Angle, rad
$\dot{\phi}$	Roll Rate, rad/sec
$\dot{\psi}$	Yaw Rate, rad/sec
ω_B	Break Frequency of Turbulence Model, rad/sec
ω_n	Natural Frequency, rad/sec

SECTION I

INTRODUCTION

The task of shipboard landing for a vertical takeoff and landing (VTOL) aircraft involves four subtasks.

(1) Up-and-away flight to maneuver within a mile or so of the ship. This requires the same kind of maneuvering as a conventional wingborne aircraft would perform.

(2) Powered-lift flight at speeds below conventional wingborne flight. This is typical of short takeoff and landing (STOL) aircraft.

(3) Transition flight, in which the aircraft speed is reduced to the hover.

(4) Hover and low speed flight. This requires accurate positioning of the aircraft so that is can be landed, in the presence of winds and turbulence, on the moving ship.

The demands on the pilot in shipboard landing are extreme. Though pilots can perform the task with adequate safety margins, stability augmentation is required to reduce the pilot's workload in operational use.

Some augmentation systems are complex, making flying qualitites specification and analysis difficult. One way to analyze them is to match their high order responses with low order equivalent systems. This approach has been officially adopted, for the first subtask above, in the CTOL flying qualities Military Specification, MIL-F-8785C.

In this present experiment, we focused on the last two piloting subtasks. We simulated low order equivalent systems whose parameters would represent the chief features of the large number of high order systems obtainable in practice. For each task, Systems Technology Incorporated, STI, have proposed approaches and criteria which warranted investigation. In Naval Air Development Center (NADC) contract (N62269-77-C-0278), Reference 1, STI proposed two criteria for classifying system type (attitude or rate) in hover and low-speed flight. The first criterion uses a second order equivalent system to classify attitude and rate command systems using their equivalent damping and frequency. The second criterion uses the attitude time response to a stick pulse. These criteria were examined in this present study.

The blending of flight control systems from up and away flight through transition to hover and vice versa presents both the time dependent problem of how to blend the systems and over

what time span, and the problem of how various systems in transition affect the handling qualities. For example, systems which appear optimum based solely on hover and low speed investigation might be less suitable when integrated into the transition maneuver. These questions have been addressed in unpublished NASA data by Franklin and Brigadier. They investigated the blending from a rate command/attitude hold system to either an attitude command/attitude hold system or to a translation rate command system. The pitch attitude tended to 'bobble' in both blending schemes. Additional data were gathered to investigate these findings.

The MIL-F-83300 control power requirements for hover have long been challenged and argued. Data are needed which will dispel these arguments. To this end, data on control usage were gathered during this present effort.

Section II describes the simulator and presents the justification for the parameter values chosen. Section III describes the results and Section IV presents a summary, conclusions and recommendations for further work. The experimental data are documented fully in the Appendices.

SECTION II

DESCRIPTION OF THE SIMULATION

1. <u>COCKPIT, DISPLAY AND CONTROLLERS</u> - The simulation was conducted in the McDonnell AV-8B fixed base simulator cockpit, shown in Figure 1. The simulator cockpit duplicates the AV-8B cockpit geometry and control layout (Figure 2). The display consisted of a virtual image, out-the-window-scene of a DD963 destroyer at night, produced by the VITAL IV, three-window color display system.

Three VITAL IV display units are arranged about the front of the cockpit to provide a wide angle scene. Each display unit has a field-of-view of 35° by 45°. The total field-of-view is ±60° horizontally. The vertical field-of-view of the front unit is 15° up to 20° over the nose. The side units provide a vertical field-of-view of 5° up to 40° down. This arrangement is especially suited for providing ground visibility for VTOL operations. Figures 3 and 4 show the initial visual scene for the hover and transition blending tasks.

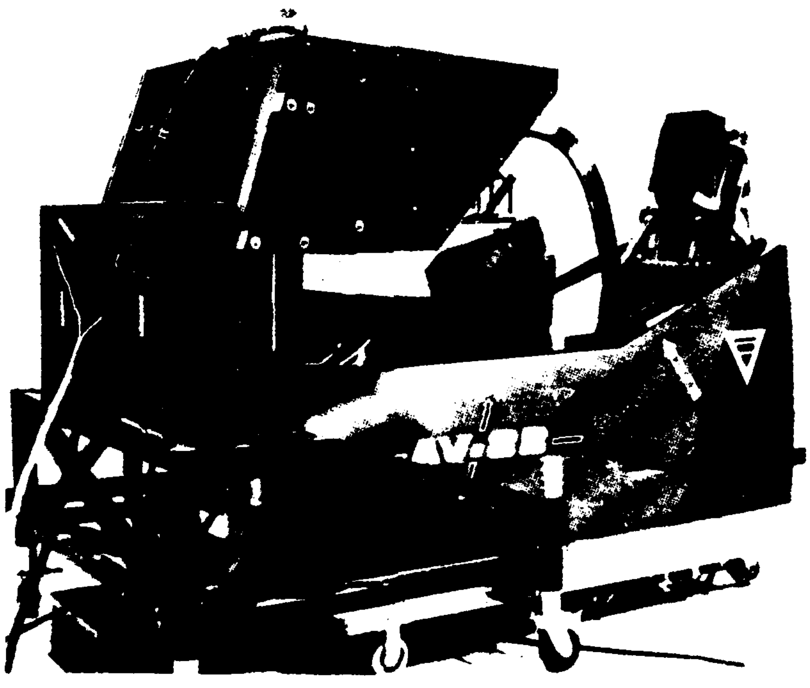

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Figure 1. AV-8B Fixed Base Simulator

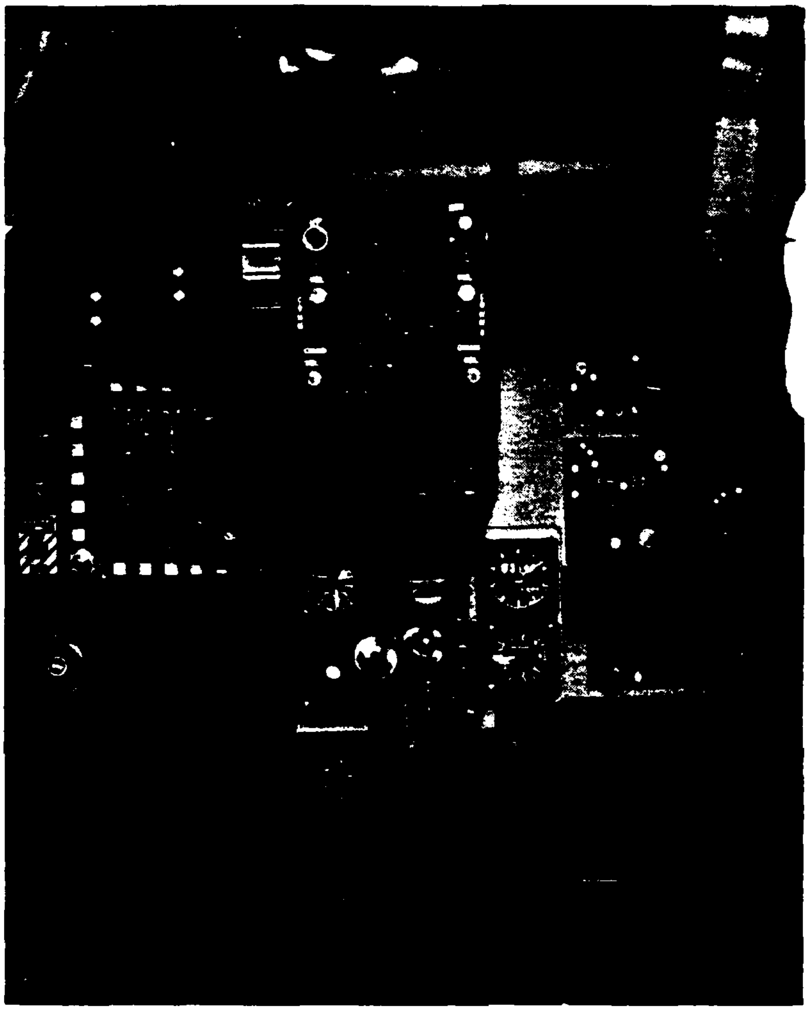

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Figure 2. AV-8B Simulator

The stick force gradients used were nominally 3.5 Newtons/cm (2.0 pounds/in) for both pitch and roll control. Position commands were used. The feel system had a bandwidth of 13 Hz and was therefore ignored in the analysis. A rudder force gradient of 28.9 Newtons/cm (16.5 pounds/in) was used throughout. The stick deflections available were ±7.6 cm (±3.0 in) laterally and ±12.7cm (±5.0 in) longitudinally. The rudder pedal travel was ±5.5cm (±2.12 in). The nozzles were fixed in the hover position. The throttle quadrant was identical to the AV-8B throttle quadrant.

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Figure 3. Pilot's View of Shipboard Landing Task Initial Condition

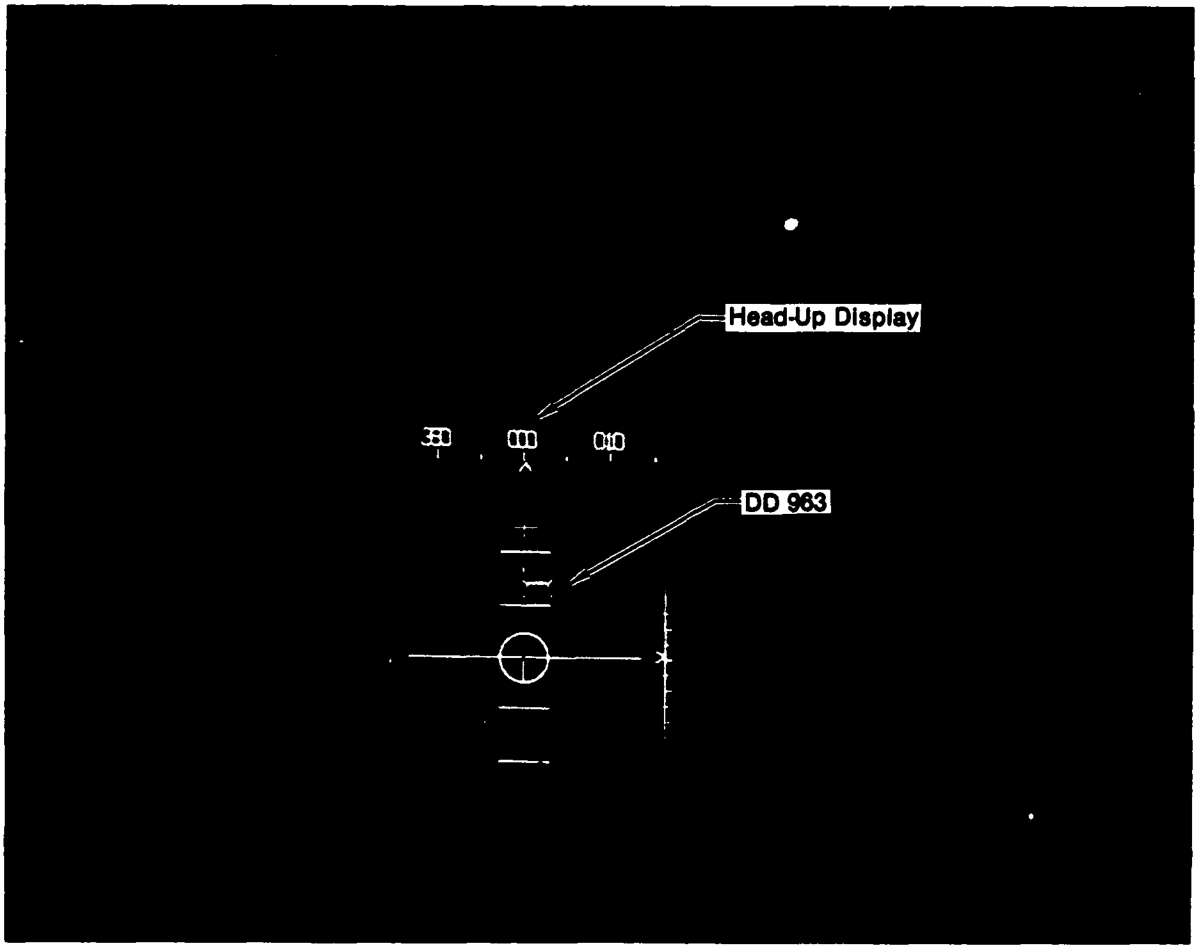


Figure 4. Pilot's View of Transition Task Initial Condition

The following data were recorded on strip-chart recorders and magnetic tape:

Lateral Stick Position

Longitudinal Stick Position

Rudder Pedal Position

Lateral Stick Force

Longitudinal Stick Force

Rudder Pedal Force

Throttle Position

Altitude

Roll Rate

Roll Angle

Pitch Rate

Pitch Angle

Yaw Rate

Yaw Angle

Gust Response (Directions & Velocities)

Wind Over Deck (Directions and Velocities)

Body-Axis Velocities u and v

N_1 (Blending Function)

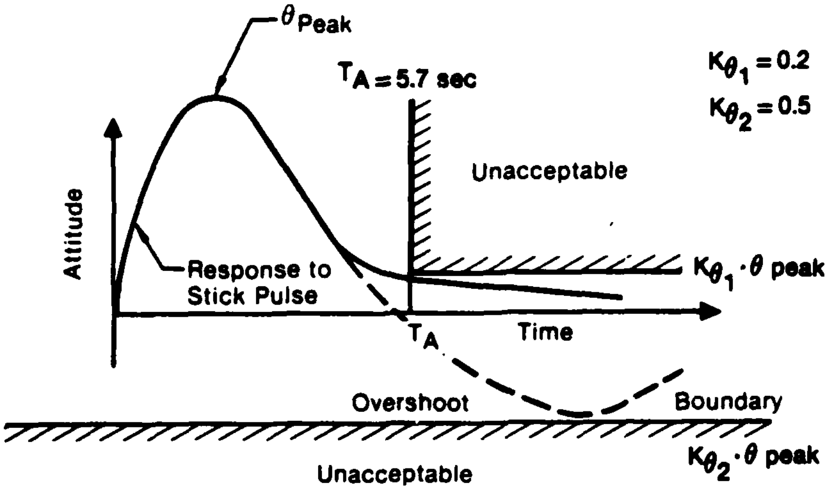
Fast Fourier analysis was used during checkout to verify the configurations. Voice recordings were made throughout the simulation.

2. CHOICE OF EXPERIMENT VARIABLES

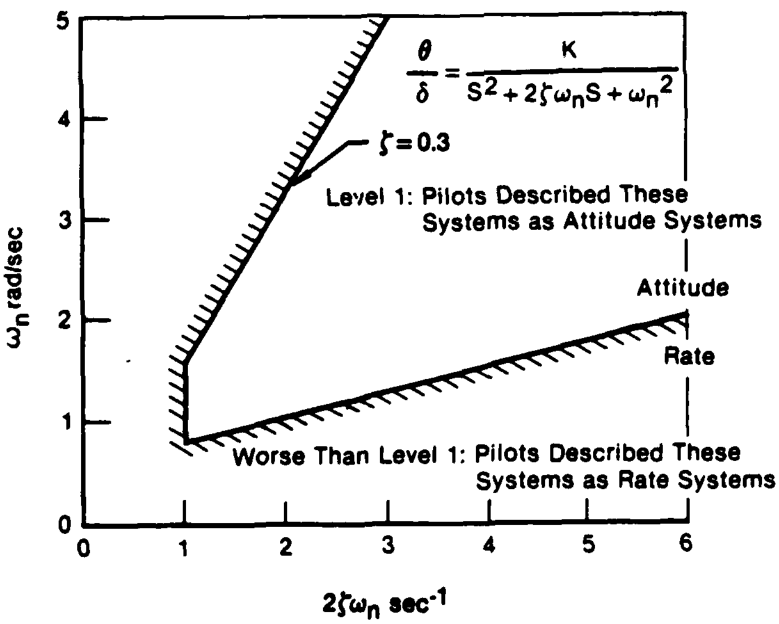
2.1 Hover and Low-Speed Flight Criteria - Augmented attitude dynamics for hover and low-speed flight can usually be classified as rate or attitude systems, according to the motion quantity effectively commanded by the pilot. Since Hoh and Ashkenas (Reference 1) have proposed that the operational use of V/STOL aircraft should be dependent on the type of system, it is important to classify systems accurately.

Figure 5 shows two classification criteria proposed by Hoh and Ashkenas. The upper figure uses the attitude time response to a stick pulse, and restricts the amount of overshoot and the time required to return to trim. The lower figure uses the damping and frequency of a second order equivalent system matched to the attitude response to pilot control.

2.2 Transition Flight Blending Schemes - Inbound transition was the task between the end of the STOL approach and hover and low-speed flight. Control system design philosophies can differ for the different flight phases. For example, for STOL approach the attitude rate may be commanded by the pilot, whereas attitude itself might be commanded in hover and low-speed flight. Figure 6 illustrates ways of blending an inbound transition from a rate to attitude system (and vice versa for an outbound transition).



Time Response Method



Equivalent System Method

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Figure 5. Classification Criteria for Attitude Systems for Low Speed and Hover Flight Reference 1

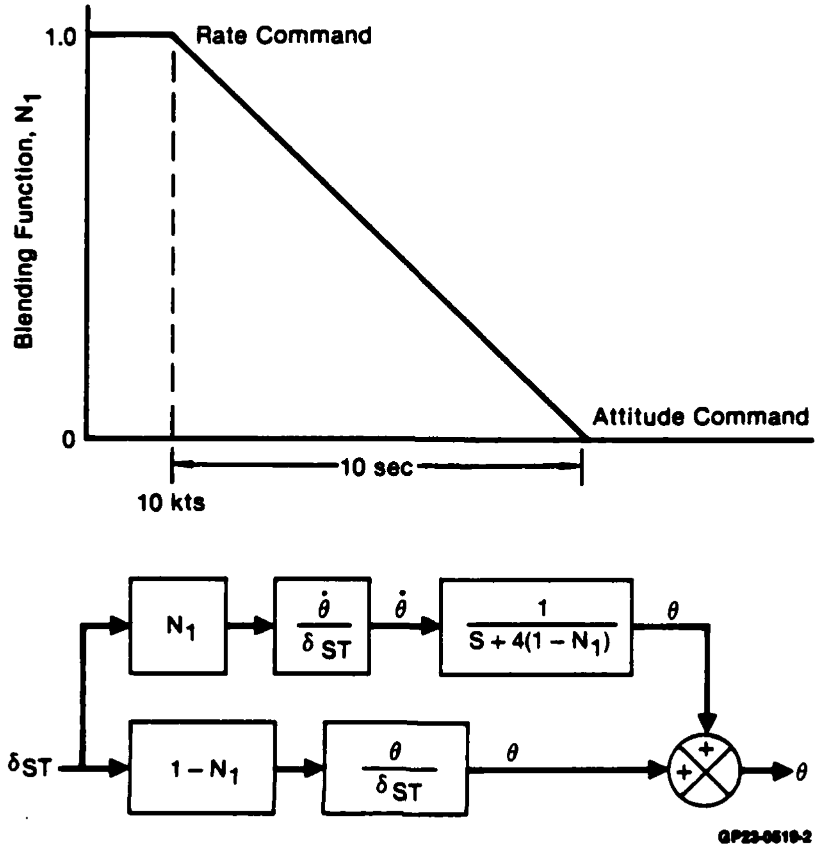


Figure 6. Example of Blending Schedule

Two results have emerged in recent work on blending schemes like these. First, control systems should be blended progressively. Abrupt discontinuities degrade flying qualities. Second, systems which appear optimum for hover and low-speed flight might be less suitable when integrated into the transition phase, as References 2 and 3 discovered.

These questions have also been addressed in unpublished NASA data by Franklin and Brigadier. They investigated the blending from rate command/attitude hold to either attitude command/attitude hold or to translation rate command. A tendency for pitch attitude to "bobble" was evident in both blending schemes. Therefore, additional data were needed to substantiate these findings.

2.3 Preferred Amount of Command Gain - MIL-F-83300 specifies control power in terms of the ability to change attitude by a specified amount in one second. Reference 1 outlined an analytical and experimental approach to define control power in terms of actual required surface or control-effector limiting characteristics.

Our effort gathered data on control usage by varying the amount of control power available. An airwake model and low frequency turbulence were used to help exercise the pilot and control system. Data were gathered in the form of time histories and pilot comments.

3. EXPERIMENT DESIGN - A generic block diagram, Figure 7, was developed which allowed easy manipulation of variables.

To create an attitude command control system, the θ and ϕ forward paths were used. During the transition blending investigation these paths were used in conjunction with the $\dot{\theta}$ and ϕ paths.

3.1 Choice of Dynamics - For hover and low speed flight, dynamics were chosen from the lower portion of Figure 5 which would evaluate the attitude/rate boundary and the time response criteria. The form of the transfer function was:

$$\frac{\theta}{\delta_{ST}} = \frac{\phi}{\delta_{ST}} = \frac{K(S+1/T)}{(S+\lambda)(S^2+2\zeta\omega_n S+\omega_n^2)}$$

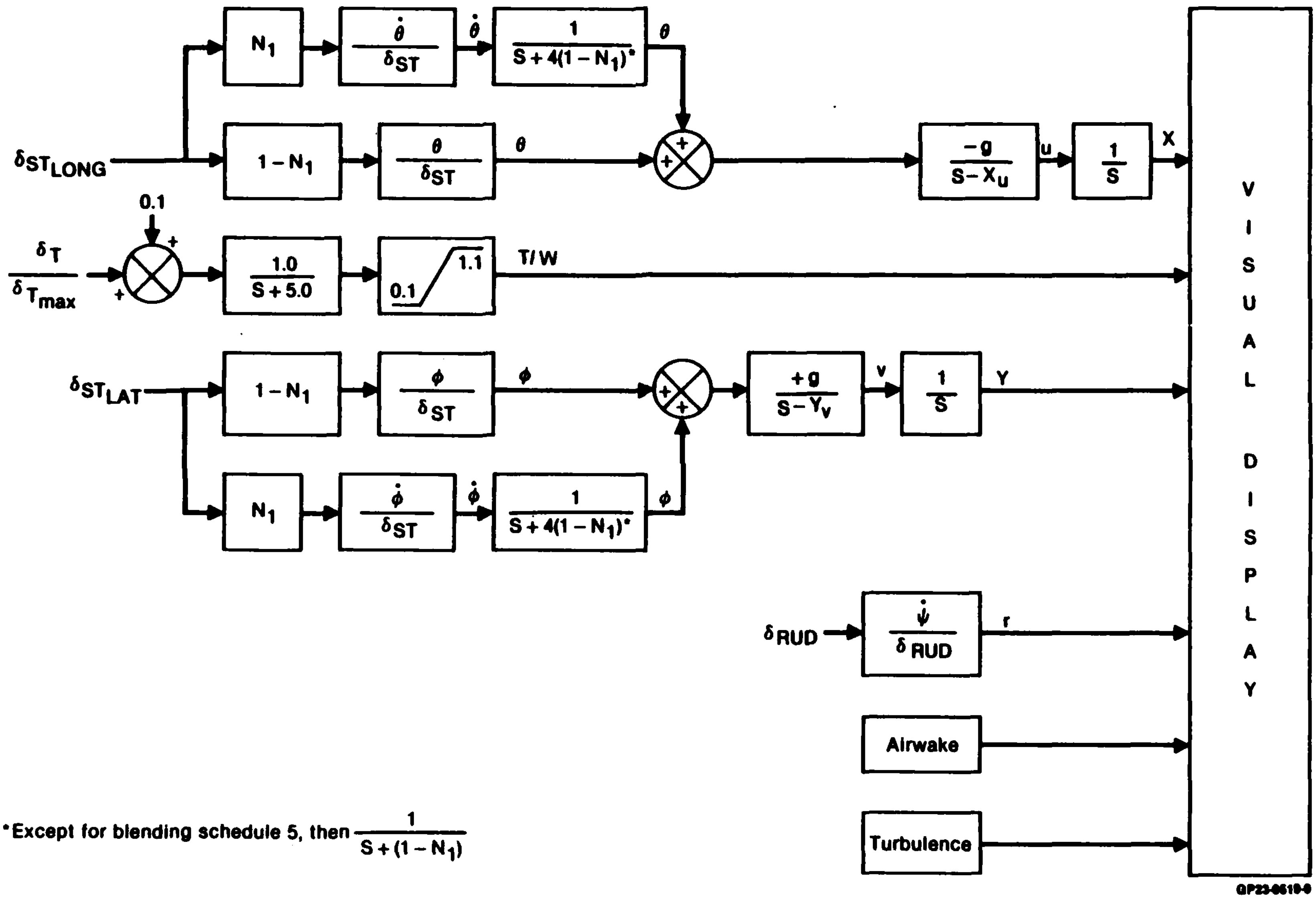
The dynamics chosen are shown in Figure 8 and tabulated in Table I. These dynamics provide a wide range of "good" and "bad" handling qualities. The steady-state stick sensitivity was varied to investigate the amount of control usage and the effect on handling qualities. The nominal steady-state stick sensitivity was based on the criterion of Reference 1.

For the transition task, rate command systems for conventional flight were blended into attitude command systems for hover and low-speed flight. Five blending schedules, at various transition speeds and over varying time spans, are shown in Figure 9. For each run, the blending schedule was identical inbound and outbound, i.e., for blending from rate to attitude command and from attitude to rate command. The airspeed had to remain below or at the transition speed for 3.0 seconds before the blending would begin. This prevented momentary airspeed changes, due to wind-over-deck or turbulence, triggering the blending scheme. The same 3.0-second criterion applied for transition to a rate command system.

3.2 Pitch Rate Dynamics - The pitch rate dynamics for the approach task were held constant and modeled by a 1st/2nd transfer function of the form:

$$\frac{\dot{\theta}}{\delta_{ST}} = \frac{.116\ \text{rad/sec}^2/\text{cm}\ (S+.252)}{(S+.25)(S+2.0)}$$

Time history responses for step and impulse functions are shown in Figure 10.



*Except for blending schedule 5, then $\frac{1}{S + (1 - N_1)}$

Figure 7. Generic Block Diagram

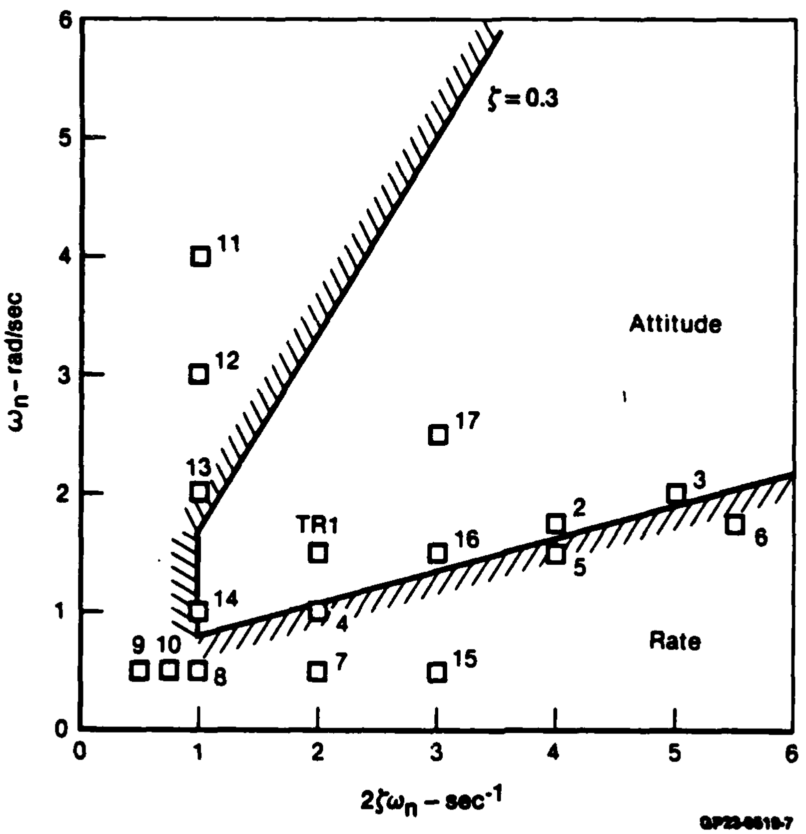


Figure 8. Configuration Location on Criterion Boundary for Attitude Systems

3.3 Roll Rate Dynamics - The roll rate dynamics for the approach task were held constant and modeled by a 0/1st transfer function of the form:

$$\frac{\dot{\phi}}{\delta_{ST}} = \frac{.081 \text{ rad/sec}^2\text{/cm}}{(s+2.0)}$$

Time history responses for step and impulse functions are shown in Figure 11.

3.4 Directional Dynamics - These were held constant and modeled by a 0/1st transfer function of the form:

$$\frac{\dot{\psi}}{\delta_{PED}} = \frac{.115 \text{ rad/sec}^2\text{/cm}}{(S+1.095)}$$

Time history responses for step and impulse functions are shown in Figure 12.

TABLE I. LIST OF CONFIGURATIONS AND PILOT RATINGS

Configuration	K rad/sec²/cm	K_{ss} rad/cm	ζ	ω_n rad/sec	λ rad/sec	1/T rad/sec	Pilot Rating A	Pilot Rating B	Pilot Rating C
TR1	0.069	0.031	0.667	1.5	—	—	7, 4	3, 7	6, 5
	0.309	0.137	↓	↓	—	—	3, 3		
	0.387	0.172	↓	↓	—	—	6, 6		
TR2	0.069	0.023	1.14	1.75	—	—	4, 7	4	5
	0.105	0.034	↓	↓	—	—	5		
	0.211	0.069	↓	↓	—	—	5		
	0.421	0.137	↓	↓	—	—	8, 3		
	0.919	0.300	↓	↓	—	—	3		
TR3	0.069	0.017	1.25	2.0	—	—	5, 4	3, 7	4
	0.137	0.034	↓	↓	—	—	4, 3		
	0.276	0.069	↓	↓	—	—	3, 4		
TR4	0.069	0.069	1.0	1.0	—	—	5, 6	6, 7	
	0.137	0.137	↓	↓	—	—	4, 6, 5		
	0.275	0.275	↓	↓	—	—	5, 6		
	0.034	0.034	↓	↓	—	—	2, 7		
TR5	0.069	0.031	1.33	1.5	—	—	6, 6, 4	7	6
	0.155	0.069	↓	↓	—	—	6, 6		
	0.309	0.137	↓	↓	—	—	3, 4		
TR6	0.069	0.023	1.57	1.75	—	—	5, 5	3, 7	4.5
	0.105	0.034	↓	↓	—	—	4, 6		
	0.211	0.069	↓	↓	—	—	4, 2		
TR7	0.1725	0.069	2.0	0.5	0.1	0.01	7, 4	5	9
	0.2	0.08		↓	↓	↓			
TR8	0.1725	0.069	1.0	↓	↓	↓	8, 8	7	9
TR9	0.1725	0.069	0.5	↓	↓	↓	7, 6	9	9
TR10	0.1725	0.069	0.75	↓	↓	↓	7, 5	8	
	0.02	0.008	↓	↓	↓	↓			9
	0.0035	0.0014	↓	↓	↓	↓			8
	0.015	0.006	↓	↓	↓	↓			10
TR10	0.137	0.003	0.75	0.5	2.0	0.01	7		
	0.206	0.004	↓	↓	↓	↓	7		
	0.859	0.017	↓	↓	↓	↓	7		
	1.718	0.034	↓	↓	↓	↓	10		
	0.137	0.018	↓	↓	3.0	0.1	10		
	0.275	0.037	↓	↓	↓	↓	4, 5		
	0.258	0.034	↓	↓	↓	↓	7		
TR11	0.272	0.017	0.125	4.0	—	—	8, 10	10	9
TR12	0.153	0.017	0.167	3.0	—	—	5, 9	9	5
TR13	0.276	0.069	0.25	2.0	—	—	9, 7, 9, 8	10	10
TR14	0.069	0.069	0.5	1.0	—	—	4, 4	7	6
	0.034	0.034	↓	↓	—	—	7		
	0.137	0.137	↓	↓	—	—	7		
TR15	0.1725	0.069	3.0	0.5	0.1	0.01	7, 7	7	8
	↓	0.004	↓	↓	2.0	↓			5
TR16	0.4658	0.069	1.0	1.5	0.3	0.1	4, 3, 4	3	3.5
TR17	0.431	0.069	0.6	2.5	—	—	9, 9	10	9.5
	0.214	0.034	↓	↓	—	—	4, 5, 6		3.5
	0.862	0.137	↓	↓	—	—	10		
	0.107	0.017	↓	↓	—	—	2, 2, 2, 4		5

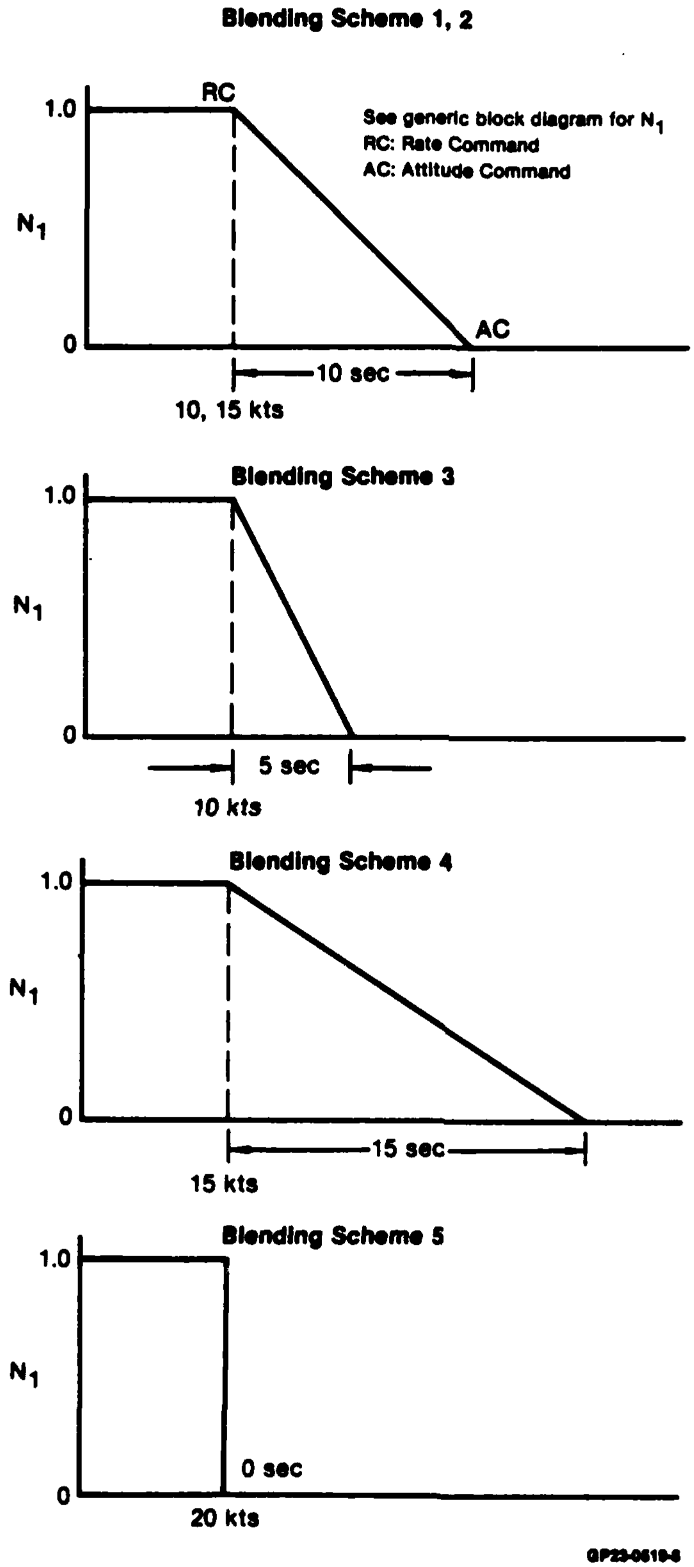
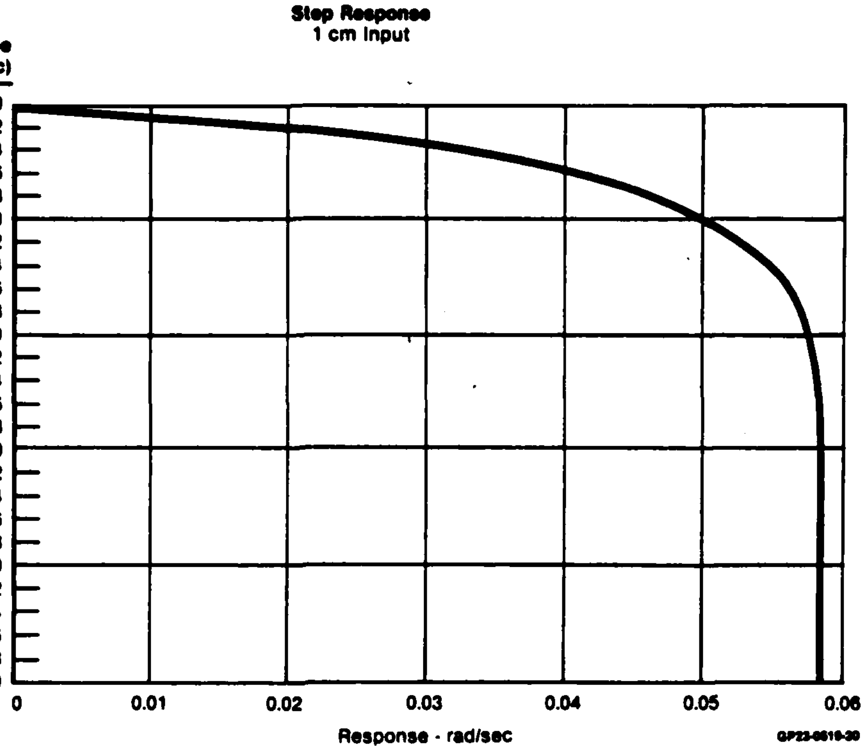


Figure 9. Blending Schedules

Tabulated Response (rad/sec)	Time (sec)
	0
0.191074E − 01	0.2
0.318978E − 01	0.4
0.404629E − 01	0.6
0.462018E − 01	0.8
0.500500E − 01	1.0
0.526332E − 01	1.2
0.543701E − 01	1.4
0.555404E − 01	1.6
0.563315E − 01	1.8
0.568684E − 01	2.0
0.572351E − 01	2.2
0.574875E − 01	2.4
0.576632E − 01	2.6
0.577872E − 01	2.8
0.578763E − 01	3.0
0.579418E − 01	3.2
0.579912E − 01	3.4
0.580296E − 01	3.6
0.580603E − 01	3.8
0.580857E − 01	4.0
0.581073E − 01	4.2
0.581261E − 01	4.4
0.581428E − 01	4.6
0.581580E − 01	4.8
0.581719E − 01	5.0



Tabulated Response (rad/sec)	Time (sec)
0.116000E + 00	0
0.776386E − 01	0.2
0.519604E − 01	0.4
0.348181E − 01	0.6
0.233377E − 01	0.8
0.156574E − 01	1.0
0.105185E − 01	1.2
0.707950E − 02	1.4
0.477738E − 02	1.6
0.323571E − 02	1.8
0.220270E − 02	2.0
0.150998E − 02	2.2
0.104491E − 02	2.4
0.732186E − 03	2.6
0.521423E − 03	2.8
0.378932E − 03	3.0
0.282172E − 03	3.2
0.216068E − 03	3.4
0.170533E − 03	3.6
0.138818E − 03	3.8
0.116407E − 03	4.0
0.100276E − 03	4.2
0.884014E − 04	4.4
0.794253E − 04	4.6
0.724379E − 04	4.8
0.668283E − 04	5.0

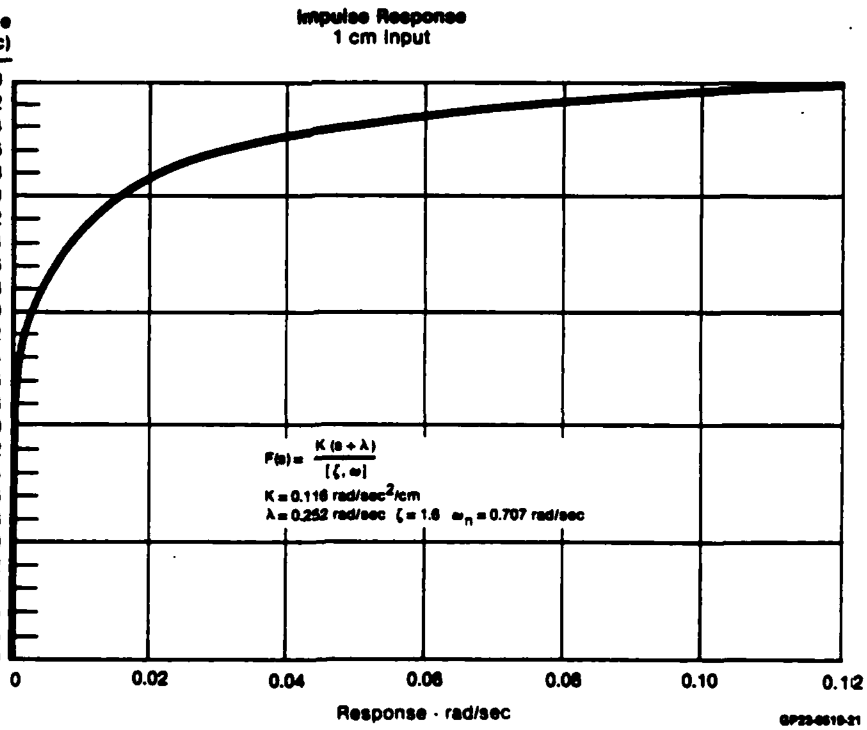
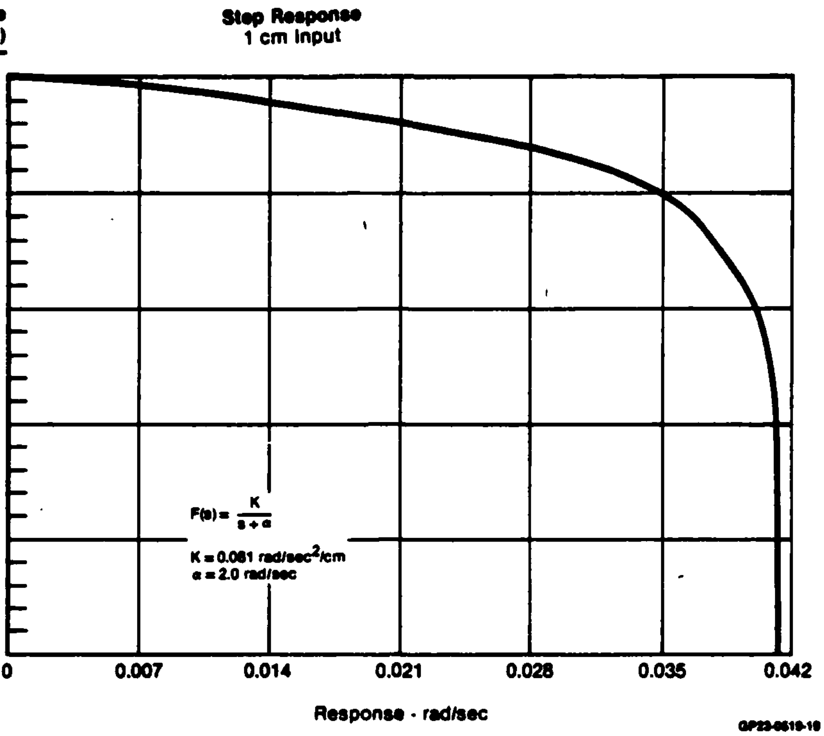


Figure 10. Pitch Rate Dynamics, $\dot{\theta}/\delta_{ST}$

Tabulated Response (rad/sec)	Time (sec)
	0
0.133520E – 01	0.2
0.223022E – 01	0.4
0.283016E – 01	0.6
0.323232E – 01	0.8
0.350189E – 01	1.0
0.368259E – 01	1.2
0.380372E – 01	1.4
0.388491E – 01	1.6
0.393934E – 01	1.8
0.397582E – 01	2.0
0.400028E – 01	2.2
0.401667E – 01	2.4
0.402766E – 01	2.6
0.403502E – 01	2.8
0.403996E – 01	3.0
0.404327E – 01	3.2
0.404549E – 01	3.4
0.404698E – 01	3.6
0.404797E – 01	3.8
0.404864E – 01	4.0
0.404909E – 01	4.2
0.404939E – 01	4.4
0.404959E – 01	4.6
0.404973E – 01	4.8
0.404982E – 01	5.0



Tabulated Response (rad/sec)	Time (sec)
0.810000E – 01	0
0.542959E – 01	0.2
0.363958E – 01	0.4
0.243967E – 01	0.6
0.163536E – 01	0.8
0.109622E – 01	1.0
0.734815E – 02	1.2
0.492562E – 02	1.4
0.330174E – 02	1.6
0.221322E – 02	1.8
0.148357E – 02	2.0
0.994465E – 03	2.2
0.666610E – 03	2.4
0.446842E – 03	2.6
0.299527E – 03	2.8
0.200779E – 03	3.0
0.134586E – 03	3.2
0.902158E – 04	3.4
0.604736E – 04	3.6
0.405368E – 04	3.8
0.271725E – 04	4.0
0.182143E – 04	4.2
0.122094E – 04	4.4
0.818419E – 05	4.6
0.548603E – 05	4.8
0.367739E – 05	5.0

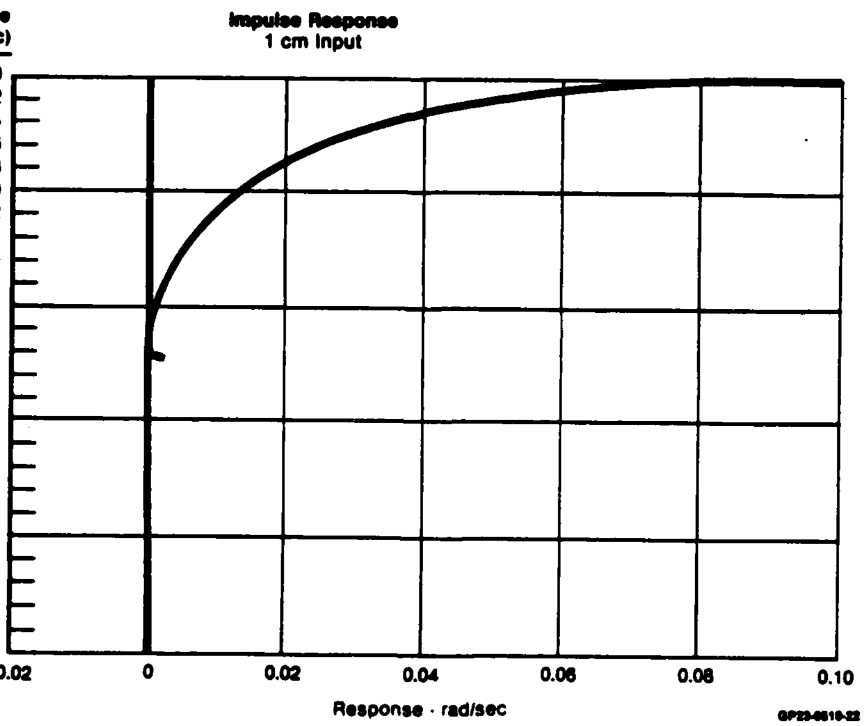
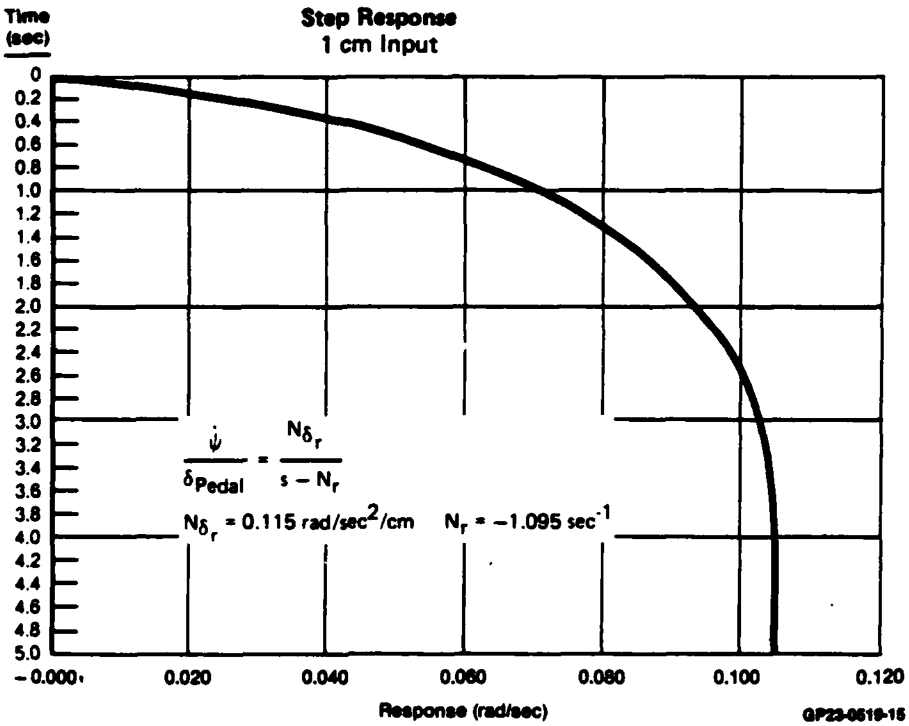


Figure 11. Roll Rate Dynamics, $\dot{\phi}/\delta_{ST}$

Tabulated Response (rad/sec)	Time (sec)
0.206557E−01	0
0.20657E−01	0.2
0.372489E−01	0.4
0.506786E−01	0.6
0.612866E−01	0.8
0.698685E−01	1.0
0.767967E−01	1.2
0.823498E−01	1.4
0.868091E−01	1.6
0.903913E−01	1.8
0.932690E−01	2.0
0.955807E−01	2.2
0.974378E−01	2.4
0.989296E−01	2.6
0.100128E+00	2.8
0.101091E+00	3.0
0.101864E+00	3.2
0.102486E+00	3.4
0.102984E+00	3.6
0.103385E+00	3.8
0.103707E+00	4.0
0.103966E+00	4.2
0.104174E+00	4.4
0.104341E+00	4.6
0.104475E+00	4.8
0.104583E+00	5.0



Tabulated Response (rad/sec)	Time (sec)
0.115000E+00	0
0.923820E−01	0.2
0.742125E−01	0.4
0.596166E−01	0.6
0.478912E−01	0.8
0.384721E−01	1.0
0.309054E−01	1.2
0.248270E−01	1.4
0.199441E−01	1.6
0.160215E−01	1.8
0.128704E−01	2.0
0.103391E−01	2.2
0.830562E−02	2.4
0.667206E−02	2.6
0.535963E−02	2.8
0.430567E−02	3.0
0.345884E−02	3.2
0.277856E−02	3.4
0.223206E−02	3.6
0.179306E−02	3.8
0.144042E−02	4.0
0.115712E−02	4.2
0.929538E−03	4.4
0.746718E−03	4.6
0.599855E−03	4.8
0.481876E−03	5.0

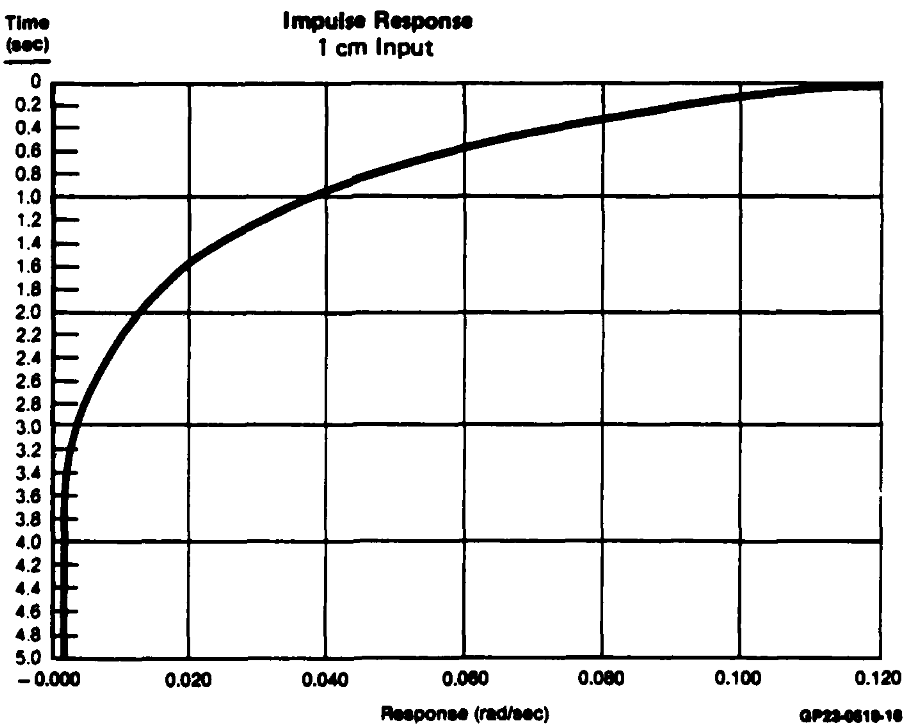
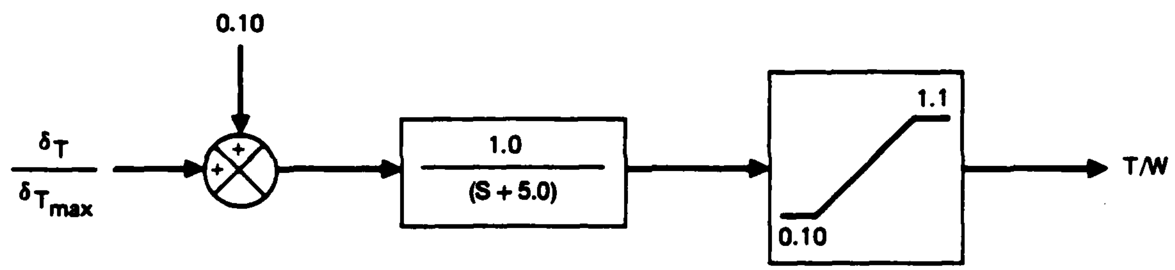


Figure 12. Directional Dynamics, $\dot{\psi}/\delta_{PED}$

3.5 Thrust-to-Throttle Dynamics - These were held constant and were modeled with a first order lag with a break frequency of 5.0 rad/sec. The maximum thrust-to-weight ratio was 1.1. Trim was set at approximately 90% throttle.

The block diagram for thrust-to-throttle response is shown in Figure 13.



$$T/W = 0.10 + \frac{\delta_T}{\delta_{T_{max}}}$$

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Figure 13. Thrust-to-Throttle Dynamics

3.6 Equations of Motion - The equations of motion used in the simulation are presented in Table II.

TABLE II. EQUATIONS OF MOTION

1. **Transfer functions yield p, q, r (body axis angular rates).**
2. **Body axis velocity components obtained from:**

$\dot{u} = -g \sin\theta + rv - qw + X_u u$ $\qquad X_u = -0.1$

$\dot{v} = g \sin\phi \cos\theta + pw - ru + Y_v v$ $\qquad Y_v = -0.1$

$\dot{w} = -pv + qu - g\,(T/W - \cos\theta \cos\phi) + Z_w w$ $\qquad Z_w = -0.75$

3. **Inertial axis displacement determined from:**

$$\dot{X} = u \cos\psi \cos\theta + v[\cos\psi \sin\theta \sin\phi - \sin\psi \cos\phi] + w\,[\cos\psi \sin\theta \cos\phi + \sin\psi \sin\phi]$$

$$\dot{Y} = u \sin\psi \cos\theta + v\,[\sin\psi \sin\theta \sin\phi + \cos\psi \cos\phi] + w\,[\sin\psi \sin\theta \cos\phi - \cos\psi \sin\phi]$$

$$\dot{Z} = -u \sin\theta + v \cos\theta \sin\phi + w \cos\theta \cos\phi$$

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Simulator display motions were driven by six degree of freedom calculations.

3.7 Wind-Over-Deck (WOD) and Turbulence - Continuous turbulence was simulated, as in Reference 4, by passing the output of a random noise generator with a relatively uniform low-frequency power spectral distribution through a first order filter with a break frequency (ω_B) of 0.314 rad/sec:

$$\frac{u_g}{N_g} = \frac{K_{u_g}}{S+0.314} \; ; \; \frac{v_g}{N_g} = \frac{K_{v_g}}{S+0.314}$$

N_g was the output of the random noise generator. K_{u_g} and K_{v_g} were selected to produce the desired turbulence intensity level of σ_g = 1.14kt (1.925 fps). Turbulence was introduced through the display rather than into the aircraft equations, along the X and Y inertial axes. This allowed the variation of aircraft parameters while keeping the turbulence response invariant.

Wind-over-deck was simulated using a simplified version of the airwake model described in Reference 5. The wind-over-deck was introduced in inertial axes through the display. The simplified wind-over-deck model is presented in Appendix D.

3.8 Head-Up Display - The head-up display, taken and modified from Reference 6, is shown in Figure 14. The aircraft symbol was fixed and the vertical ladder had rung separation scaled to 10 feet. "Longitudinal and lateral displacement from the landing pad are presented in plan view in a head-up axis system. Height above the landing pad is depicted by the separation of the double dumbbell and the airplane symbol. This is, in effect, an elevation view of the vertical situation" (Reference 6). The landing pad symbol and height "bug" flashed when the aircraft was more than 30 feet from the landing pad.

For the transition blending task, ILS crosshairs replaced the landing pad symbol and height "bug" until the aircraft was within 30.48m (100 ft) longitudinally of the landing pad. At that position the HUD became identical to that for hover and low-speed flight, as described above.

3.9 Pilot Task - In the hover and low speed flight simulation, the aircraft was initially at an altitude of 19.2m (63 ft) with a 14.8 kts (25 fps) forward speed and offset 30.48m (100 ft) laterally and 152.4m (500 ft) longitudinally from the hover point. The task was to translate forward and to the right and stabilize in hover over the landing pad. Once hover was established, the pilot attempted to land the aircraft on the landing pad.

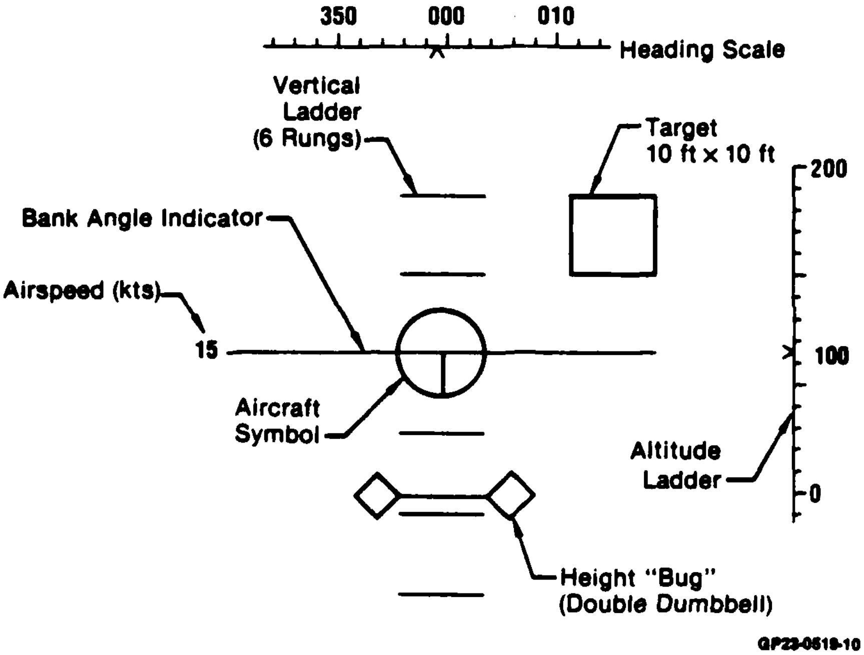


Figure 14. Head Up Display

For the transition blending investigation, the aircraft was initially at an altitude of 56.39m (185 ft) with a 40 kts (67.56 fps) forward speed and offset 30.48m (100 ft) laterally and 804.5m (0.5 mi) longitudinally from the hover point. The task was to fly down a 4° glide slope, blend into an attitude command control system, establish a hover approximately 4.57m (15 ft) above the landing pad and then perform an accelerating, climbing left turn. The accelerating, climbing left turn was used to expose any discontinuities or changes in piloting technique due to the blending of control systems.

A pictorial view of both pilot tasks is presented in Figure 15.

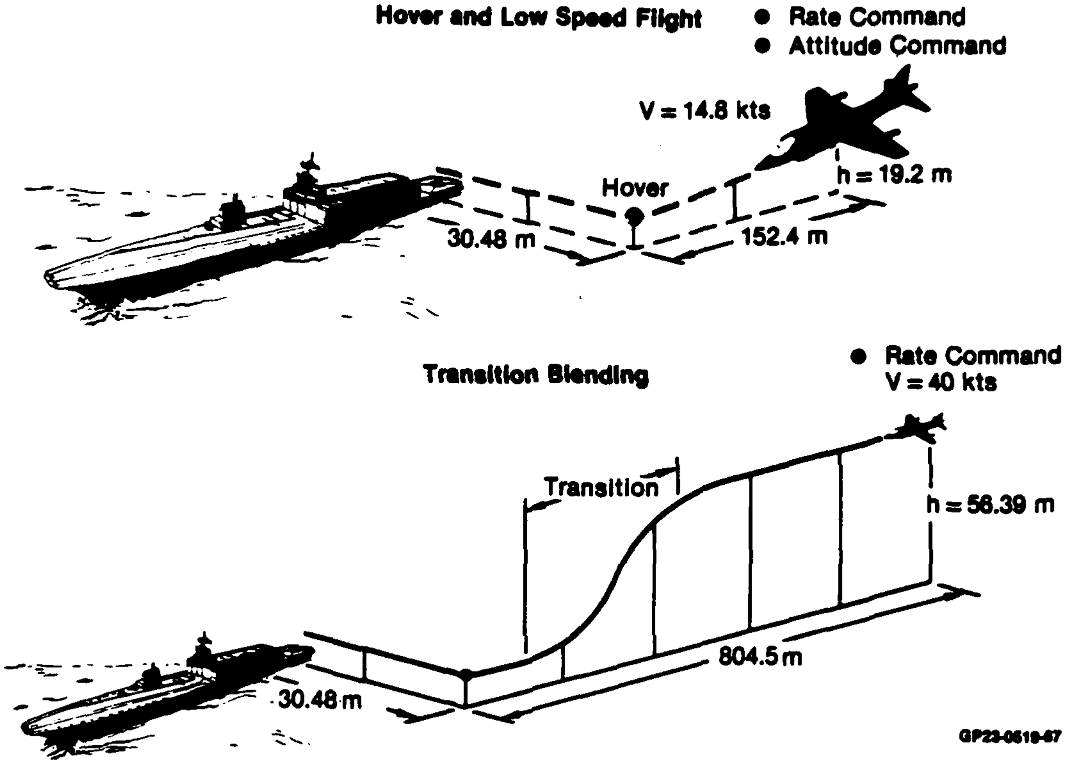
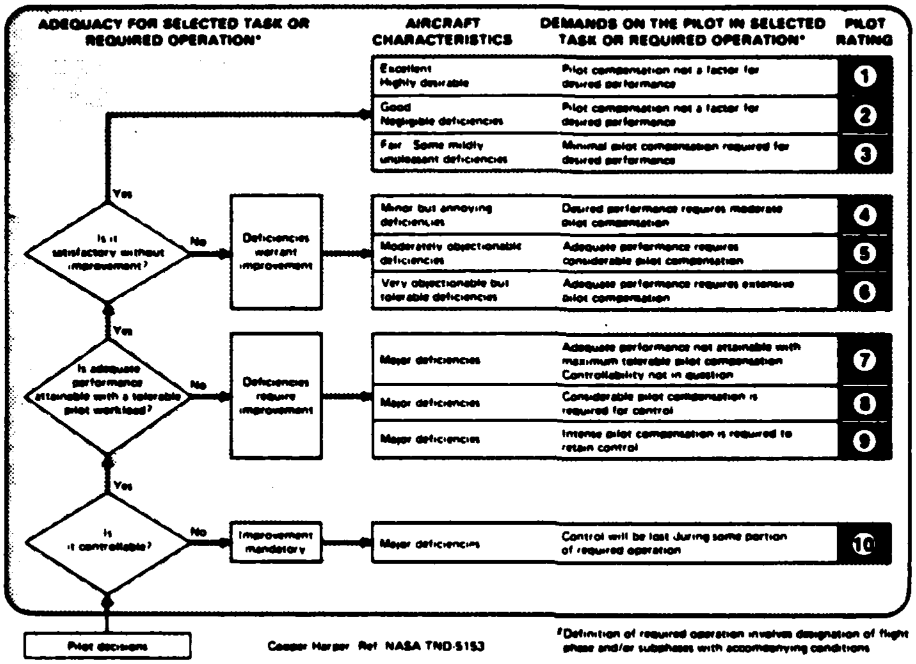


Figure 15. Description of Pilot Task

3.10 <u>Pilot Comments and Ratings</u> - The pilot was asked to fly and evaluate each configuration without attempting, for example, to compare different configurations. This allows the pilot to concentrate on the piloting task. Contrasting configurations were presented to aid in obtaining unbiased rating results. The pilot was unaware of the parameters of the configuration he was evaluating.

Pilot comments and Cooper-Harper ratings were recorded after each run.

The Cooper-Harper pilot rating scale together with definitions of terms from the scale are presented in Figure 16.



DEFINITIONS FROM TN-D-5153

COMPENSATION

The measure of additional pilot effort and attention required to maintain a given level of performance in the face of deficient vehicle characteristics

HANDLING QUALITIES

Those qualities or characteristics of an air craft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role

MISSION

The composite pilot-vehicle functions that must be performed to fulfill operational requirements May be specified for a role, complete flight, flight phase, or flight subphase

PERFORMANCE

The precision of control with respect to aircraft movement that a pilot is able to achieve in performing a task (Pilot-vehicle performance is a measure of handling performance Pilot performance is a measure of the manner or efficiency with which a pilot moves the principal controls in performing a task)

ROLE

The function or purpose that defines the primary use of an aircraft

TASK

The actual work assigned a pilot to be performed in completion of or as representative of a designated flight segment

WORKLOAD

The integrated physical and mental effort required to perform a specified piloting task

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Figure 16. Cooper-Harper Pilot Rating Card

SECTION III

RESULTS OF THE SIMULATION

1. EFFECTS OF THE DISPLAY - The VITAL IV night display was considered by the pilots to be very realistic for simulating conditions close to the ship.

2. HEAD-UP DISPLAY - The HUD was very helpful close to the ship. When the aircraft was directly over the landing pad, the pilot relied on the HUD to provide the location of the aircraft relative to the landing pad.

3. TIME RESPONSE CRITERION FOR HOVER AND LOW-SPEED - System dynamics, Table I, were chosen with reference to the attitude classification boundary shown in the lower portion of Figure 5. These dynamics were then compared with the time response criterion (top portion of Figure 5). The impulse time responses for all configurations are presented in Appendix A. The pilots flew these dynamics, commented whether they were attitude or rate dynamics and assigned a Cooper-Harper pilot rating. These results are summarized in Table III.

An attitude command system was mechanized in this flight phase, so that there was a finite steady state attitude in response to a steady pilot command. However, the transient dynamics in some cases appeared to the pilots more representative of rate command systems. The pilots' interpretation of the dynamics agreed with the time response classification except for the following five configurations.

The time response criterion classified TR7 as a rate system but the pilots classified it as an attitude system. The pilots commented that the response was sluggish and that they had difficulty classifying the system. This may be due to the low stick sensitivity which would help to disguise the system response. It is hypothesized that if the stick sensitivity was increased the pilots would have less difficulty classifying the response.

TR9 and TR10 were interpreted as rate systems by the pilots and were classified as attitude systems by the time response criterion. However, the values of T_A, time to 20% of peak attitude, were close to the attitude boundary value of 5.7 seconds. The boundary value may need to be reduced. Also, the gain of the systems may have been too low to allow an accurate pilot evaluation.

The damping for TR11 and TR12 may have been too low to allow accurate pilot evaluation. The pilots had difficulty flying them for all values of gain, and commented that they were PIO-prone. The pilots did, however, speculate that the dynamics were attitude responses. These configurations show that the time response criterion not only classifies the dynamics but imposes a damping limit for attitude systems.

TABLE III. Time Response Criterion Summary Sheet

System	System Classification		Pilot Ratings and Comments		
	Time Response	Attitude System Boundary	A	B	C
TR1	Attitude	Attitude	7, 4 Attitude	3, 7 Attitude	6, 5 Attitude
TR2	Attitude	Attitude	4, 7 Attitude	4 Attitude	5 Attitude
TR3	Attitude	Attitude	5, 4 Attitude	3, 7 Attitude	4 Attitude
TR4	Attitude	Rate	5, 6 Attitude	6, 7 Attitude	
TR5	Attitude	Rate	6, 6, 4 Attitude	7 Attitude	6 Attitude
TR6	Attitude	Rate	5, 5 Attitude	3, 7 Attitude	4.5 Attitude
TR7	Rate	Rate	7, 4 Rate, Attitude	5 Attitude	9 Attitude
TR8	Rate	Rate	8, 8 Rate, Attitude	7 Rate	9 Rate
TR9	Attitude	Rate	7, 6 Rate	9 Rate	9 Rate
TR10	Attitude	Rate	7, 5 Rate	8 Rate	9, 8, 10 Attitude
TR11	Rate	Rate	8, 10 Attitude	10 Attitude	9 Attitude
TR12	Rate	Rate	5, 9 Attitude	9 Attitude	5 Attitude
TR13	Attitude	Rate	9, 7, 9, 8 Rate, Attitude	10	9 Attitude
TR14	Attitude	Attitude	4, 4, 7, 7 Attitude	7 Attitude	6 Attitude
TR15	Rate	Rate	7, 7 Attitude, Rate	7 Rate	8, 5 Rate, Attitude
TR16	Attitude	Attitude	4, 3 Attitude	3 Attitude	3.5 Attitude
TR17	Attitude	Attitude	9, 9, 4, 10 Attitude	10 Attitude	9, 5, 3.5, 5 Attitude

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Pilot comments and flying qualities levels for the dynamics are presented in Figure 17. The comments indicate that the response sensitivity was important. Changing the sensitivity can make a Level 3 system become a Level 1 system. An example is system TR17 which received Level 3 ratings when the steady-state stick sensitivity (K/ω_n^2) was .069 rad/cm. When the gain was reduced to .017 rad/cm the pilot rating became Level 1.

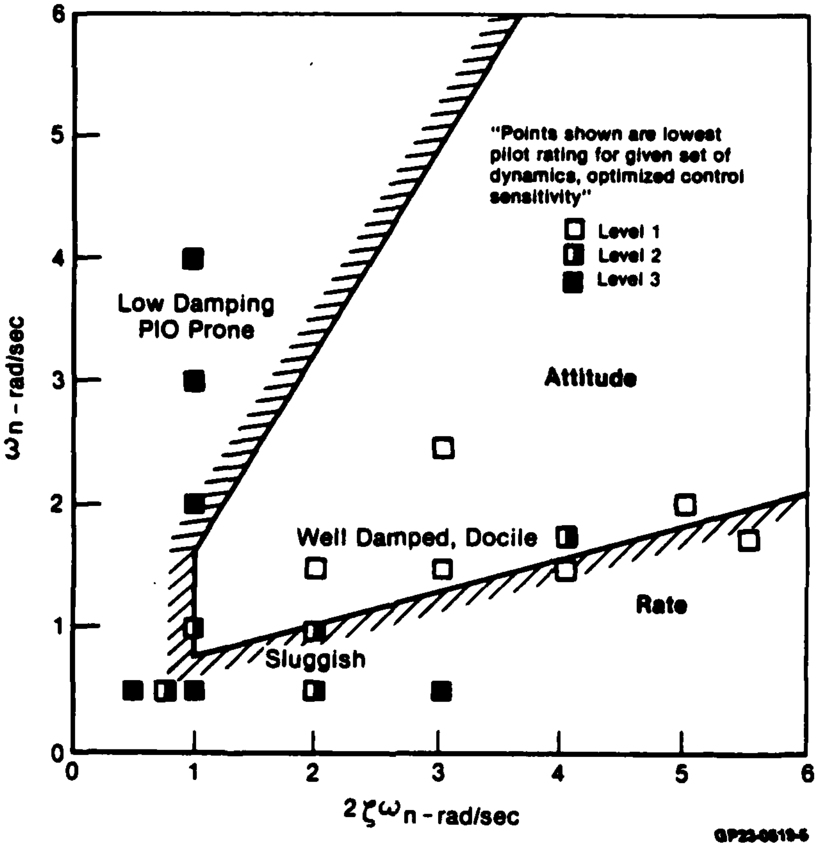


Figure 17. Pilot Rating Correlation with Criterion Boundary for Attitude Systems

Some systems were on the borderline of attitude and rate systems according to the equivalent system attitude classification boundary of Figure 5. These had both attitude and rate characteristics, according to pilot comments, when the steady-state gain was adjusted to optimize handling qualities. The task of distinguishing between attitude and rate systems was then very difficult and puzzling for the pilot. For example, the following comments were made about configuration TR5 when K_{ss} = 0.137 rad/cm.

> "I think you finally learned how to build a rate system that flies ... or is it? Sometimes it feels like a rate, sometimes it feels like an attitude. It has a lot of the attributes of a rate system. I put it somewhere it tends to stay there. If I hold it somewhere, it doesn't continue to accelerate. I'm gonna have to say it's some variation of a rate system. Dynamics are not too bad. I guess I'd like just a shade faster acceleration, but all told, it's a pretty docile animal. Cooper-Harper 3."

This would indicate the equivalent system boundary shown in Figure 5 is useful when the static sensitivity is within certain limits. However, the time response criterion is superior for discriminating between attitude and rate systems.

4. <u>EFFECTS OF STICK SENSITIVITY ON HANDLING QUALITIES AND CONTROL USAGE</u> - Following is a detailed discussion of some configurations for which steady-state sensitivity was varied. In general, these show that

- o There is an optimum gain, with low values described as sluggish and high values as over-sensitive.
- o Systems with low gain are often interpreted by the pilots as having excessive damping, whereas high gains are interpreted as having poor (little) damping.
- o Control stick usage is at a minimum when handling qualities are optimum.

Figures 18, and 19 present typical strip chart recordings of Pilot A's lateral and longitudinal stick deflections for four steady-state stick sensitivites (K_{ss}). The data shown are for Configuration TR17, ζ = 0.6 and ω_n = 2.5 rad/sec, which according to Figure 5 should be an excellent system. Figure 20 presents Pilot C's repeat runs of the two intermediate sensitivities.

The stick activity in both axes appears very similar for the lower steady-state stick sensitivites of 0.017 rad/cm and 0.034 rad/cm, (Figure 18). There was a slight increase in lateral stick usage for K_{ss} = 0.034 rad/cm. Typical comments were "just a shade quick" but "not too bad" for K_{ss} = 0.034 rad/cm. When K_{ss} was increased to 0.069 rad/cm the stick activity was markedly reduced and the pilot ratings (PR) degraded from Level 1 and 2 to Level 3. The pilots commented that the response was "too sensitive" with "low damping". By reducing their stick activity, the pilots apparently were trying to avoid pilot induced oscillations (P.I.O.). However, as K_{ss} was increased further to 0.137 rad/cm, the stick motions became rapid and large. This high sensitivity made the aircraft P.I.O. - prone and difficult to control, with a pilot rating of 10.

Figures 21 through 24 present strip chart recordings of lateral and longitudinal stick deflections for various stick sensitivities. The data shown are for Configuration TR2 (ζ= 1.14 and ω_n = 1.75 rad/sec). This configuration is close to the rate/attitude boundary shown in Figure 5. The expected pilot rating would be about 3.5.

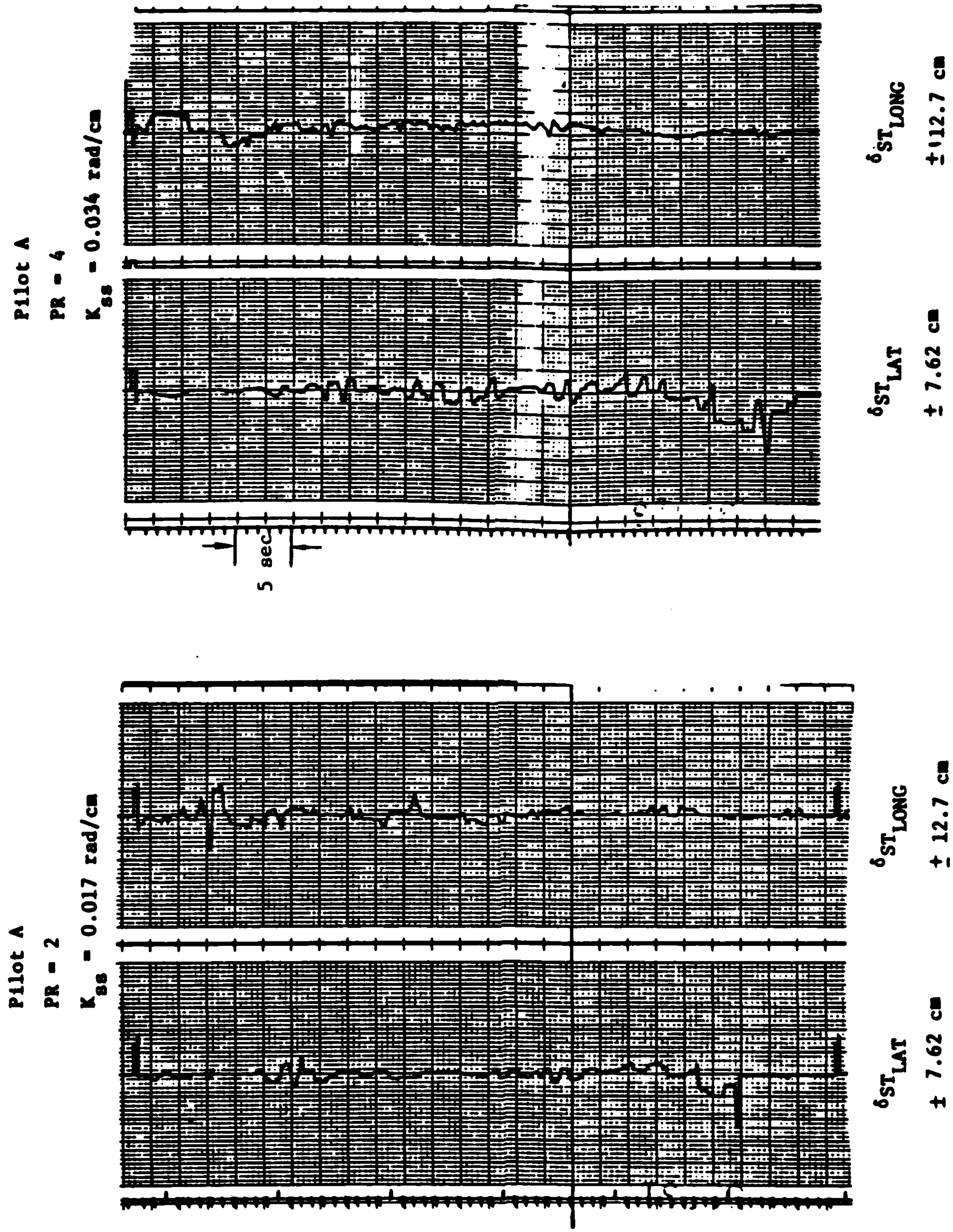


Figure 18. Strip Chart Recordings, Configuration TR17, Pilot A

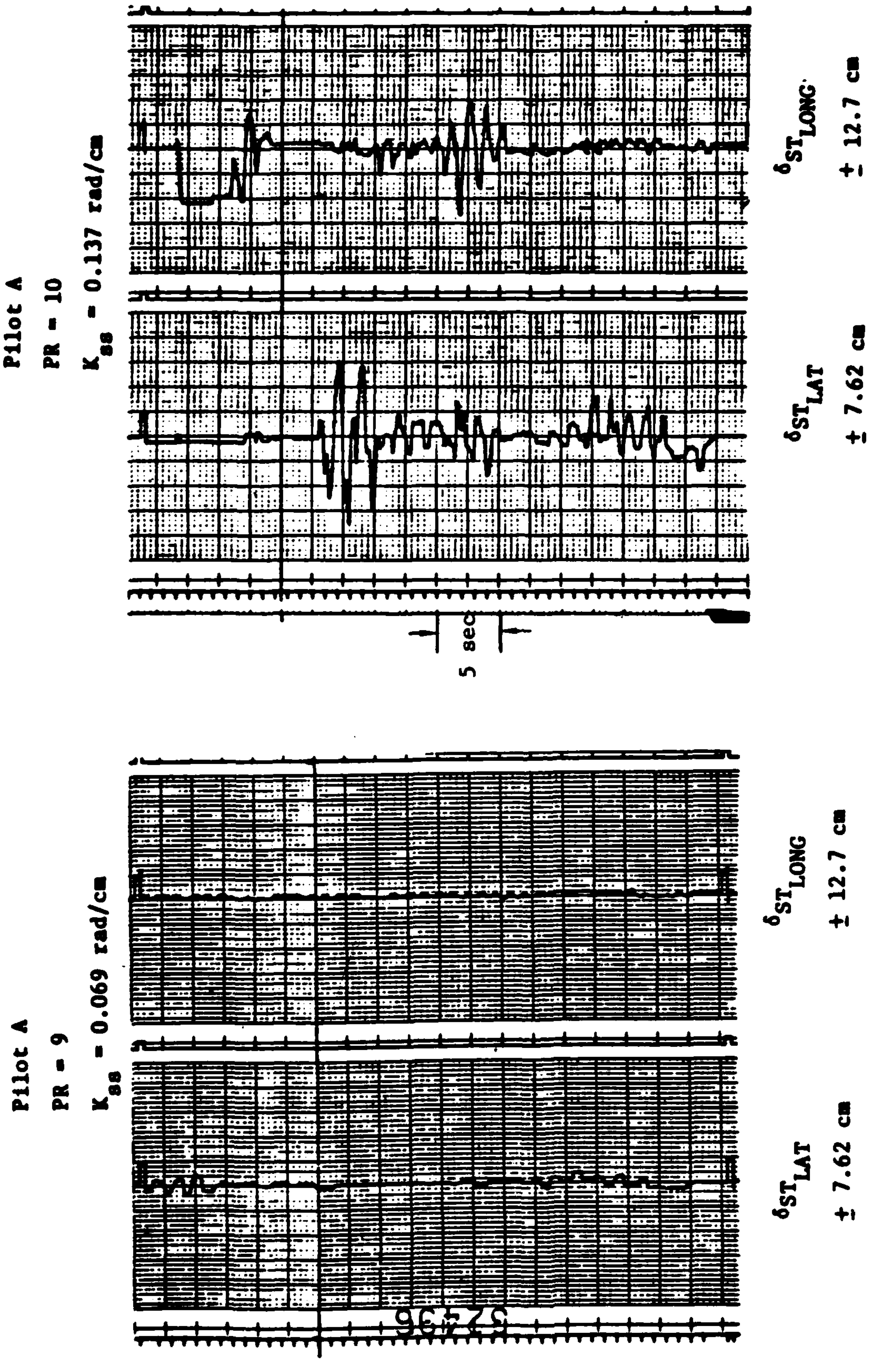


Figure 19. Strip Chart Recordings, Configuration TR17, Pilot A

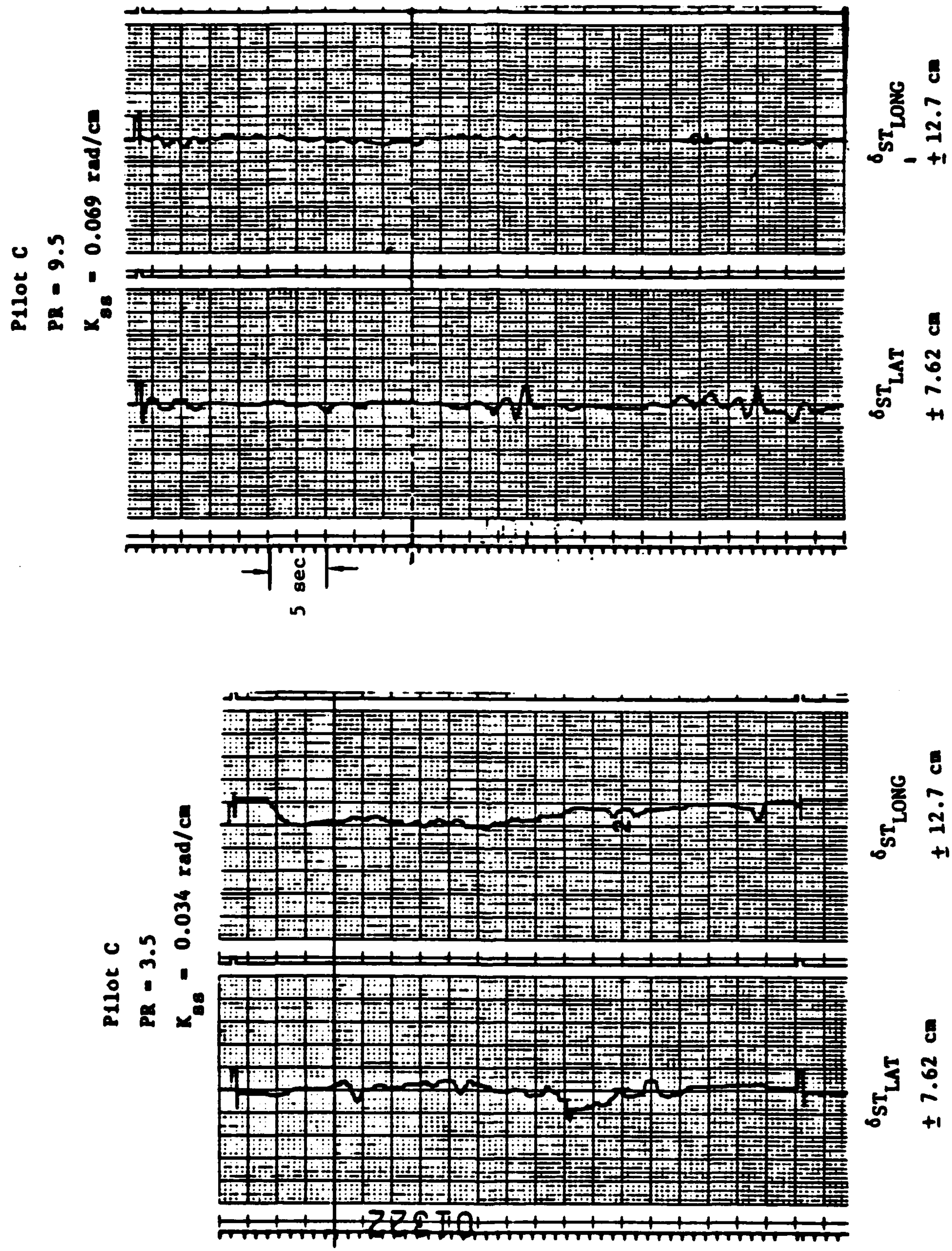


Figure 20. Strip Chart Recordings, Configuration TR17, Pilot C

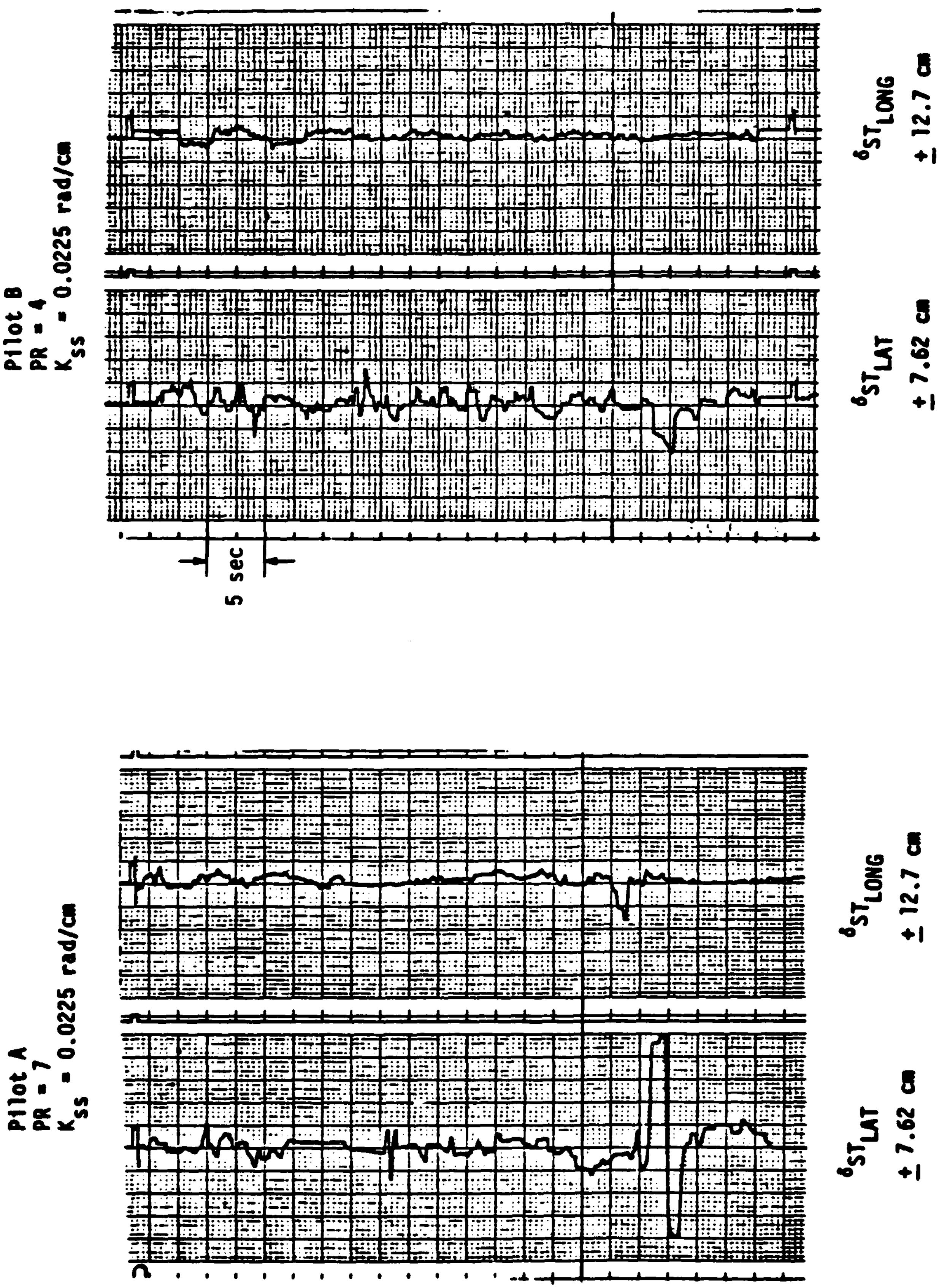


Figure 21. Strip Chart Recordings, Configuration TR2, Pilots A and B

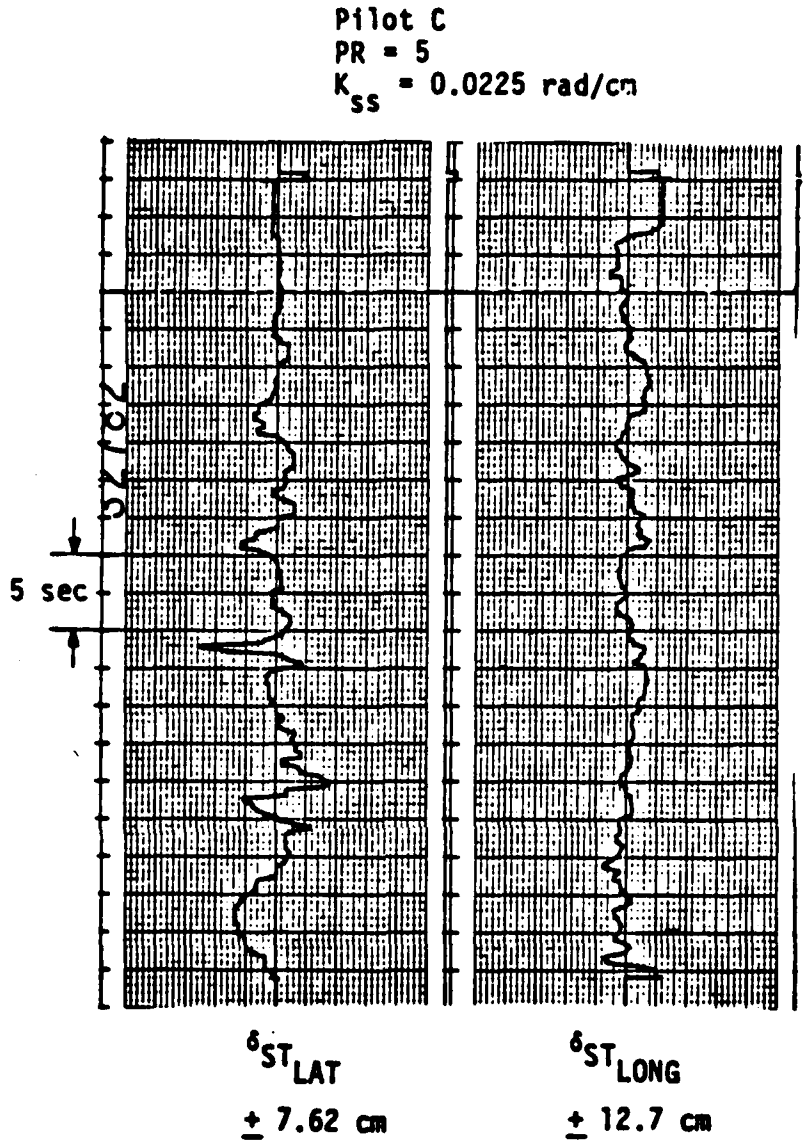


Figure 22. Strip Chart Recordings, Configuration TR2, Pilot C

A comparison between pilots of Configuration TR2, with a steady-state stick sensitivity of 0.0225 rad/cm, is presented in Figures 21 and 22. The ratings and traces show differences between pilots, who however agreed that the configuration was unsatisfactory. Pilot A commented that the "sensitivity is low" and "inadequate for shipboard use", giving a rating of 7. Pilot B commented "it's nicely damped" and gave a rating of 4. Pilot C commented that the "damping is good" but the aircraft was "sluggish", giving a rating of 5.

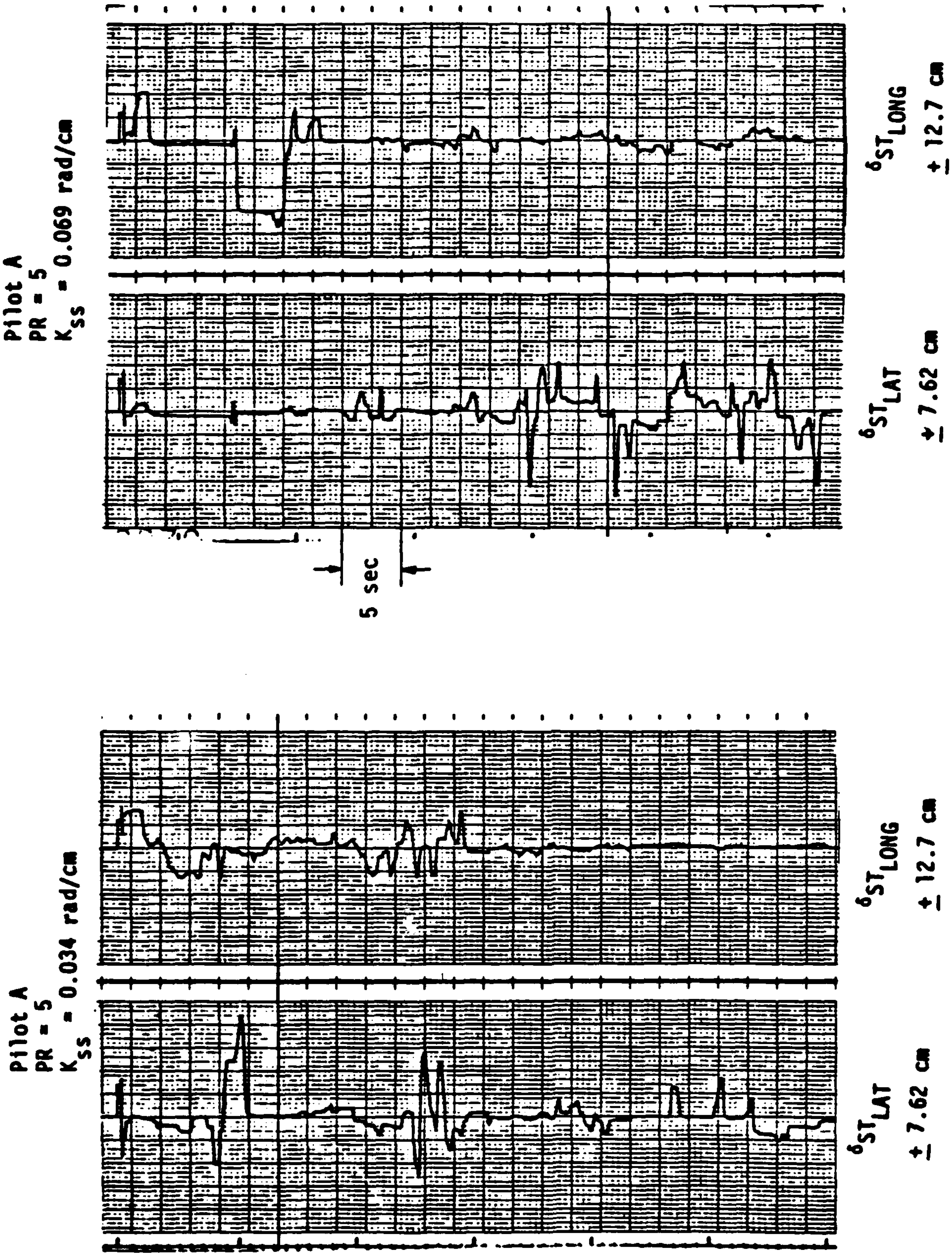


Figure 23. Strip Chart Recordings, Configuration TR2, Pilot A

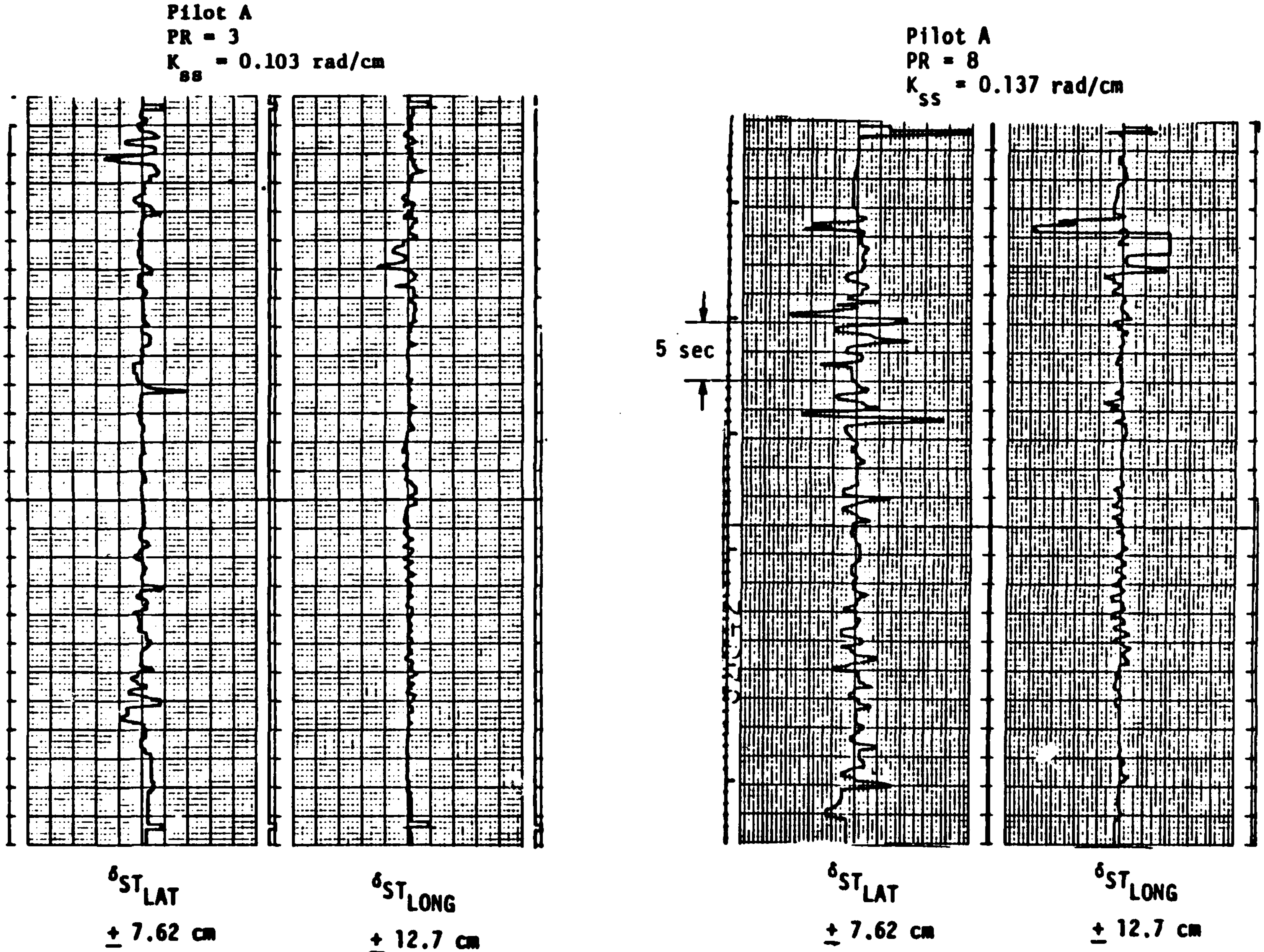


Figure 24. Strip Chart Recordings, Configuration TR2, Pilot A

Figures 23 and 24 present Pilot A's data for configuration TR2 with increasing steady-state stick sensitivities. With a sensitivity of 0.034 rad/cm, the comments were "adequate control" but "needs a little more response". With the sensitivity increased to 0.069 rad/cm, the response became "puzzling" and looked like "a blend between attitude and rate" command. When the sensitivity was further increased to 0.103 rad/cm, (Figure 24), the stick activity decreased and the pilot rating improved from 5 to 3. The pilot had "very precise control over what you're doing for this task...", however it "may be a shade abrupt in flight". This indicates a lower value of stick sensitivity may be ideal for a real airplane. As the sensitivity was then increased to 0.137 rad/cm, (also in Figure 23), the stick activity increased to that shown for a sensitivity of 0.069 rad/cm, with a pilot rating degraded to 8. The comments were "very fast dynamics and very, very high gain", "controllability becomes a question" and "it's probably unacceptable for use in close confines because of the high gain and that's primarily the controllability question".

Figures 25 and 26 present time histories of configuration TR5 (ζ = 1.33 and ω_n = 1.5 rad/sec) data with a steady-state stick sensitivity of 0.031 rad/cm. The system received pilot ratings of 6 from Pilots A and C, and a rating of 7 from Pilot B. The pilots comments included "sensitivity is low and the rate of build-up is low", "It's just damped too much. When you put a deflection (in), you really have to go full stick before you get any movement at all "and" it seemed very, very sluggish".

Configuration TR5 was also investigated with stick sensitivities of 0.069 and 0.137 rad/cm (Figure 27). At a sensitivity of 0.069 rad/cm, the pilot commented he had to "over-drive it to get an acceptable level of performance" and he would "rattle the stick around and nothing happens". He gave the system a pilot rating of 6 because of the sluggishness of the response. When the stick sensitivity was increased to 0.137 rad/cm, the pilot commented "it's very responsive to a stick input ... the static gain is relatively high". The responsiveness of the system helped improve the pilot rating to 4.

The time histories show that, very roughly, the pilots used 15% of the available lateral stick deflection. More control usage (up to 100%) was evident in a P.I.O. When handling qualities were optimum, control usage was as little as 5% (e.g., Figure 24, configuration TR2).

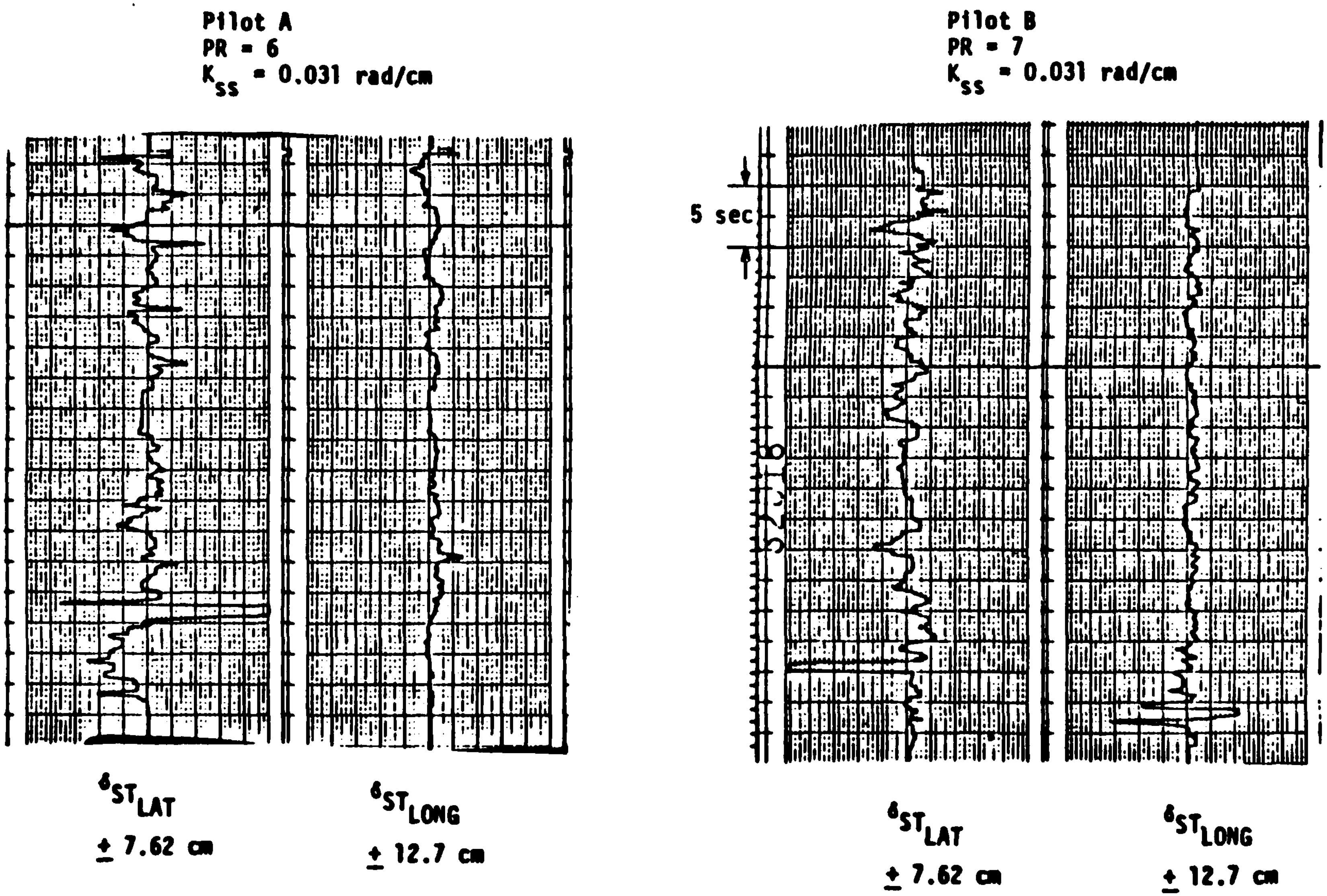


Figure 25. Strip Chart Recordings, Configuration TR5, Pilots A and B

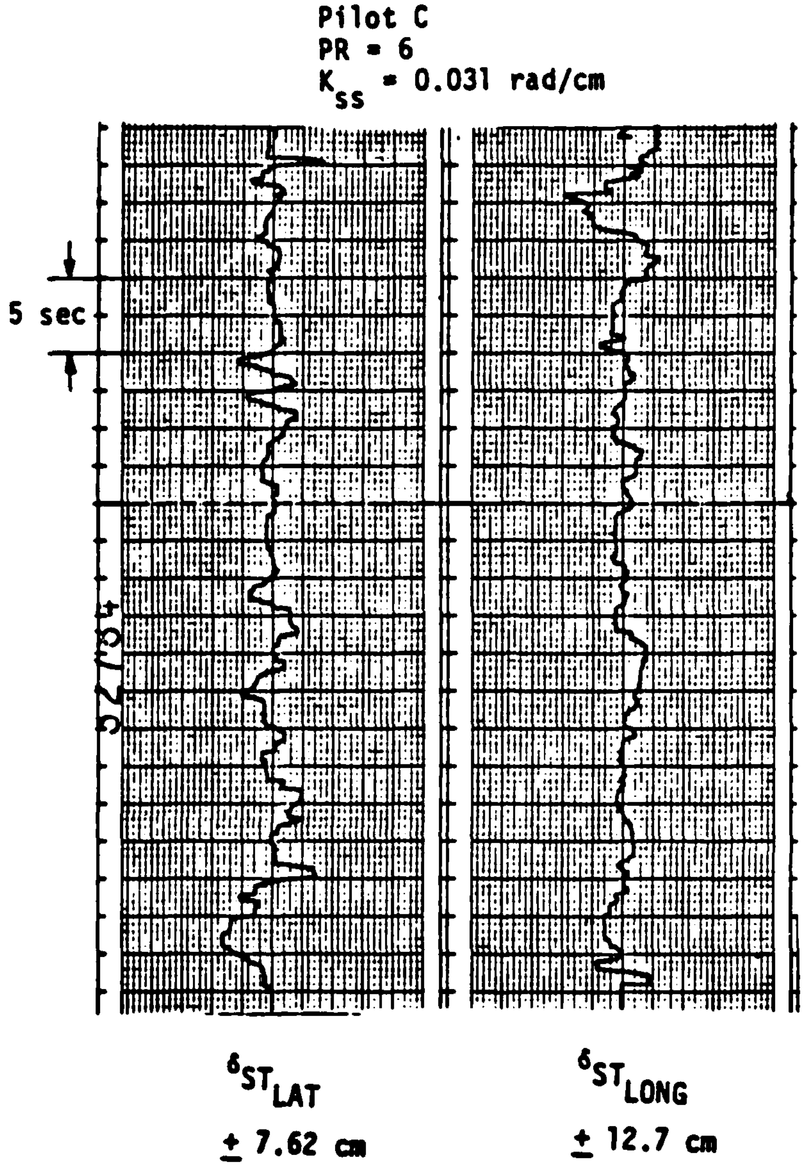


Figure 26. Strip Chart Recordings, Configuration TR5, Pilot C

5. <u>STEADY-STATE GAIN CRITERION</u> - An existing criterion from Reference 1, was used as a guideline in determining the nominal steady-state stick sensitivity (Figure 28). However, this nominal sensitivity was found to be unacceptable in some cases. Examination of pilot ratings and comments from the present simulation suggests a change in the criterion as shown in Figure 28. The proposed boundary is much more restrictive and tightens the acceptable frequency band to $1.0 \leq \omega_n \leq 2.65$ rad/sec for Level 1 handling qualities. Additional data are needed to verify the proposed boundary.

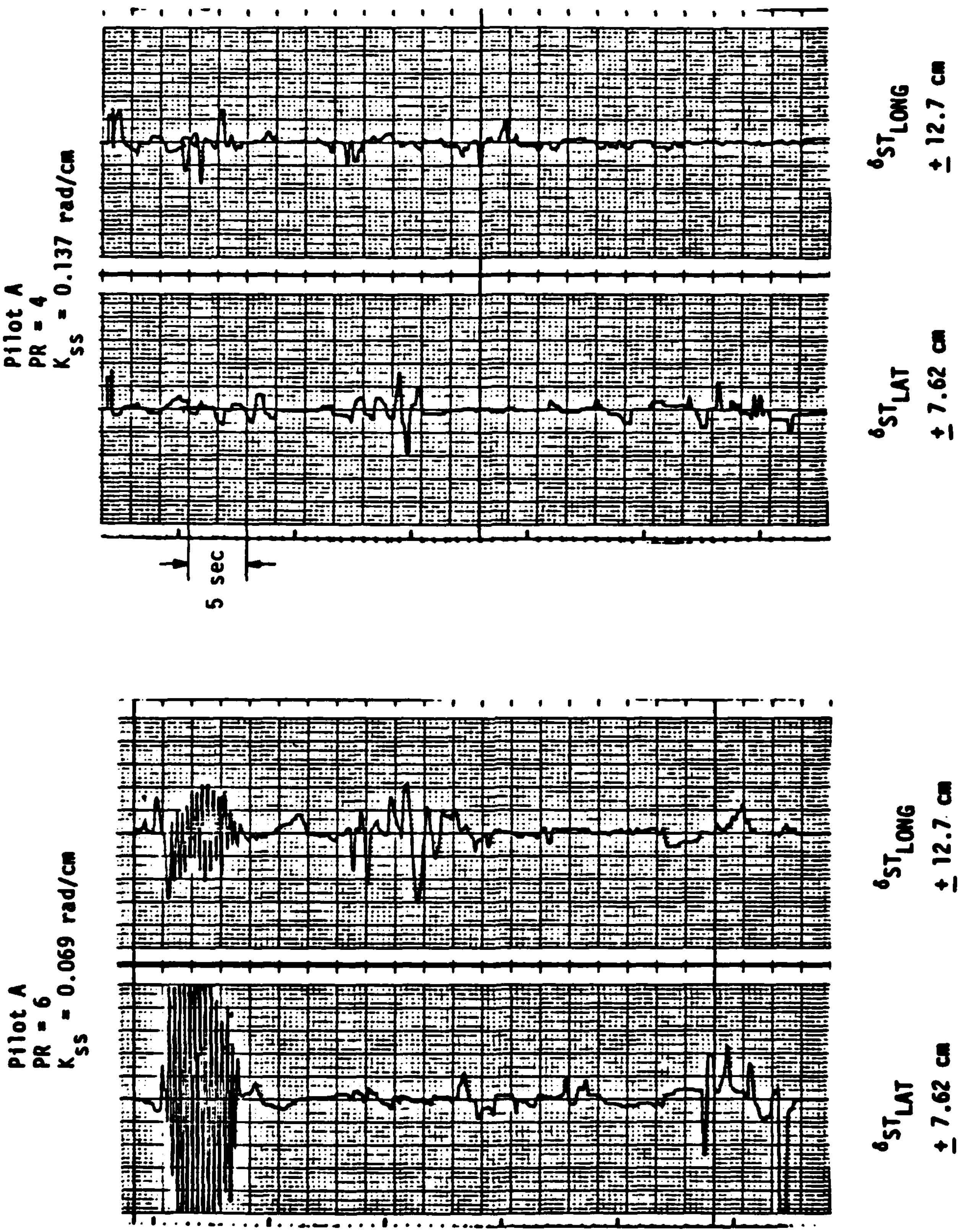


Figure 27. Strip Chart Recordings, Configuration TR5, Pilot A

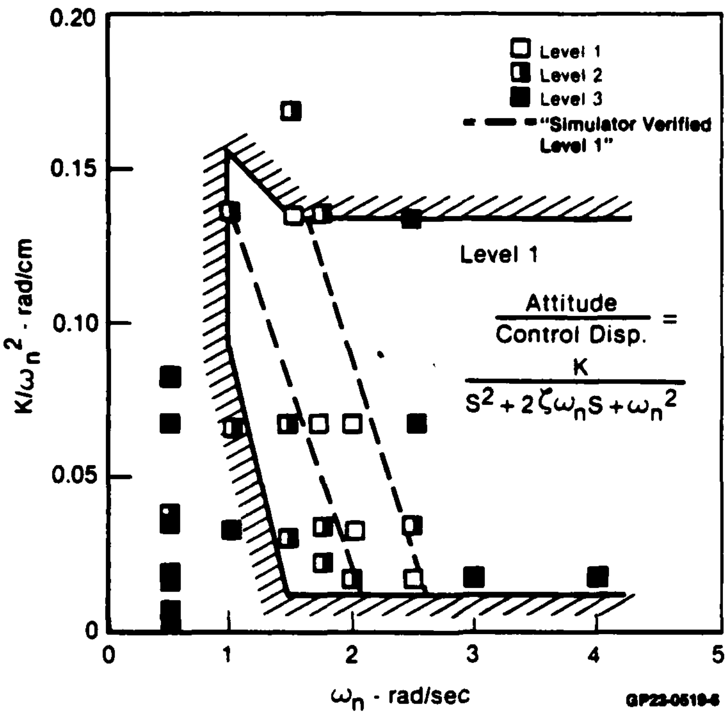


Figure 28. Steady-State Gain Criterion

6. <u>CONTROL BLENDING DURING TRANSITION</u> - The pilot comments indicate that a 10 second control system blend, initiated at 10 kts, is about optimum for transition from conventional to hover flight. Figure 29 illustrates this blend schedule. A shorter blend time was desired for the transition from hover to conventional flight. The pilot comments suggest that even with an optimum blending schedule, the static sensitivities need to be blended also. That is, a static sensitivity suitable for conventional flight may not be suitable for hover and low-speed flight. This indicates the command gain schedule was not ideal.

The pilots also complained about abrupt aircraft nose drop when blending from a rate to an attitude command system. This usually occurred with a blend instantaneously initiated at 20 kts. For example, as the pilots were approaching the ship, in a rate command system, they would set up a nose-up approach attitude and then neutralize the stick input. When the control system blended to an attitude command system, the neutral stick input would command the aircraft nose to drop. Because this occurred instantaneously, the pilot had to adjust his piloting technique quickly. The pilots felt this was unacceptable, and even dangerous.

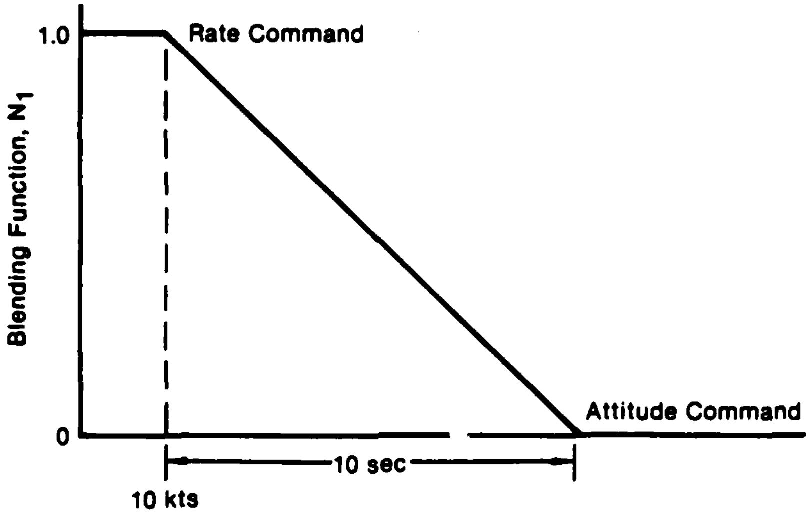


Figure 29. Optimum Inbound Transition Blending Schedule

A preference for a 10-second blend for inbound transition, noted in the unpublished NASA work, was confirmed. The preference for a shorter blend in outbound transition was also confirmed although a preferred finite time span was not established. Though the pilots did not refer to pitch bobble per se, as in the NASA work, they sometimes noted large stick forces developing during the transition. At present, therefore, it appears that some additional degree of pilot adaptation is necessary during transition to cope with the blending mechanization. Therefore, the piloting task should be organized to allow increased concentration during this flight phase.

SECTION IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A fixed-base simulation was conducted of attitude command V/STOL dynamics in hover and low-speed flight, and of control system blending during transition. The experiment simulated a visual shipboard approach and landing using a computer-generated, color, out-the-window scene, with a head-up display. The steady-state stick sensitivity was varied to gather information about the handling quality characteristics. Several control system blending schedules were investigated to determine the optimum blending technique between rate command and attitude command control systems and vice versa. Low order equivalent parameters were used to verify handling quality criteria.

A time response criterion was shown to be a better discriminator of attitude command and rate command systems than an equivalent system criterion in hover and low-speed flight. Variation of the steady-state stick sensitivity produced a wide range of pilot ratings (Level 1 to Level 3) for a given system. The present sensitivity criterion was found to be too lenient. A more restrictive modification was proposed.

In transition, the blending schemes developed earlier by Franklin and Brigadier of NASA appeared optimum. A 10 second blend from rate command was found acceptable by the pilots. The pilots desired a shorter blend from attitude command to rate command.

Some future work is suggested by this experiment:

1. Further investigation of blending schedules for transition from a hover flight control system to a conventional flight control system, including how to incorporate the schedules in an equivalent system format.

2. Further investigation of steady-state stick sensitivity requirements, including more quantitative analysis of control usage in the shipboard landing task.

3. Investigation of the attitude classification boundary. It seems likely that a better classification scheme, based on equivalent system parameters, could be derived.

REFERENCES

1. Hoh, R.H., and Ashkenas, I.L., Development of VTOL Flying Qualities Criteria for Low Speed and Hover, NADC-77052-30, December 1979.

2. Lebacqz, J.V. and Aiken, E.W., A Flight Investigation of Control, Display and Guidance Requirements for Deceleration Descending VTOL Instrument Transition Using the X-22A Variable Stability Aircraft, Calspan Corp. Report AK-5336-F-1, Sept. 1975.

3. Niessen, F.R., Kelly, J.R., Garren Jr., J.R., Yenni, K.R., and Person, L.H. The Effect of Variation in Controls and Displays on Helicopter Instrument Approach Capability, NASA TND-8385, February 1977.

4. Carpenter, C.G., and Hodgkinson, J., V/STOL Equivalent Systems Analysis, NADC-79141-60, May 1980.

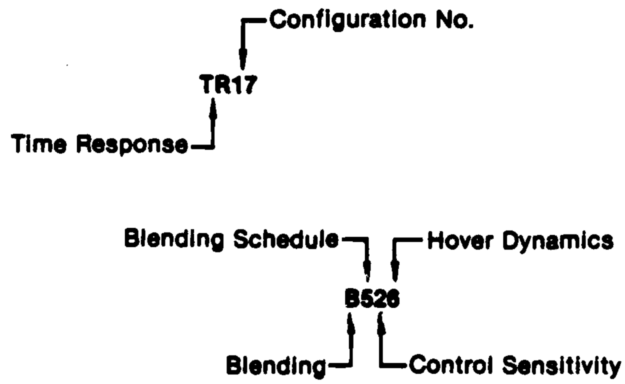
5. Stapleford, R.L., Clement, W.F., Heffley, R.K., and Booth, C.G., Flight Control/Flying Qualities Investigation for Lift/cruise Fan V/STOL, Vol. III Simulator Model, NADC 77143-30, August 1977.

6. Radford, R.C., and Andrisani, D., An Experimental Investigation of VTOL Flying Qualities Requirements in Shipboard Landing, AIAA Paper 80-1625, August 1980.

APPENDIX A

CONFIGURATION DATA

A listing of each configuration and a configuration key are presented. Frequency responses and time responses to a unit impulse input are presented.



Blending Schedules
1 - 10 sec @ 10 kts
2 - 10 sec @ 15 kts
3 - 5 sec @ 10 kts
4 - 15 sec @ 15 kts
5 - 0 sec @ 20 kts

Control Sensitivity
1 - 0.034 rad/cm (5°/in.)
2 - 0.069 rad/cm (10°/in.)
3 - 0.103 rad/cm (15°/in.)
4 - 0.137 rad/cm (20°/in.)
5 - 0.051 rad/cm (7.5°/in.)

Hover Dynamics
1 - N1LAT
2 - N2LAT
3 - TR4
4 - TR5
5 - TR14
6 - TR17

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Figure A-1. Key to Configuration Listing

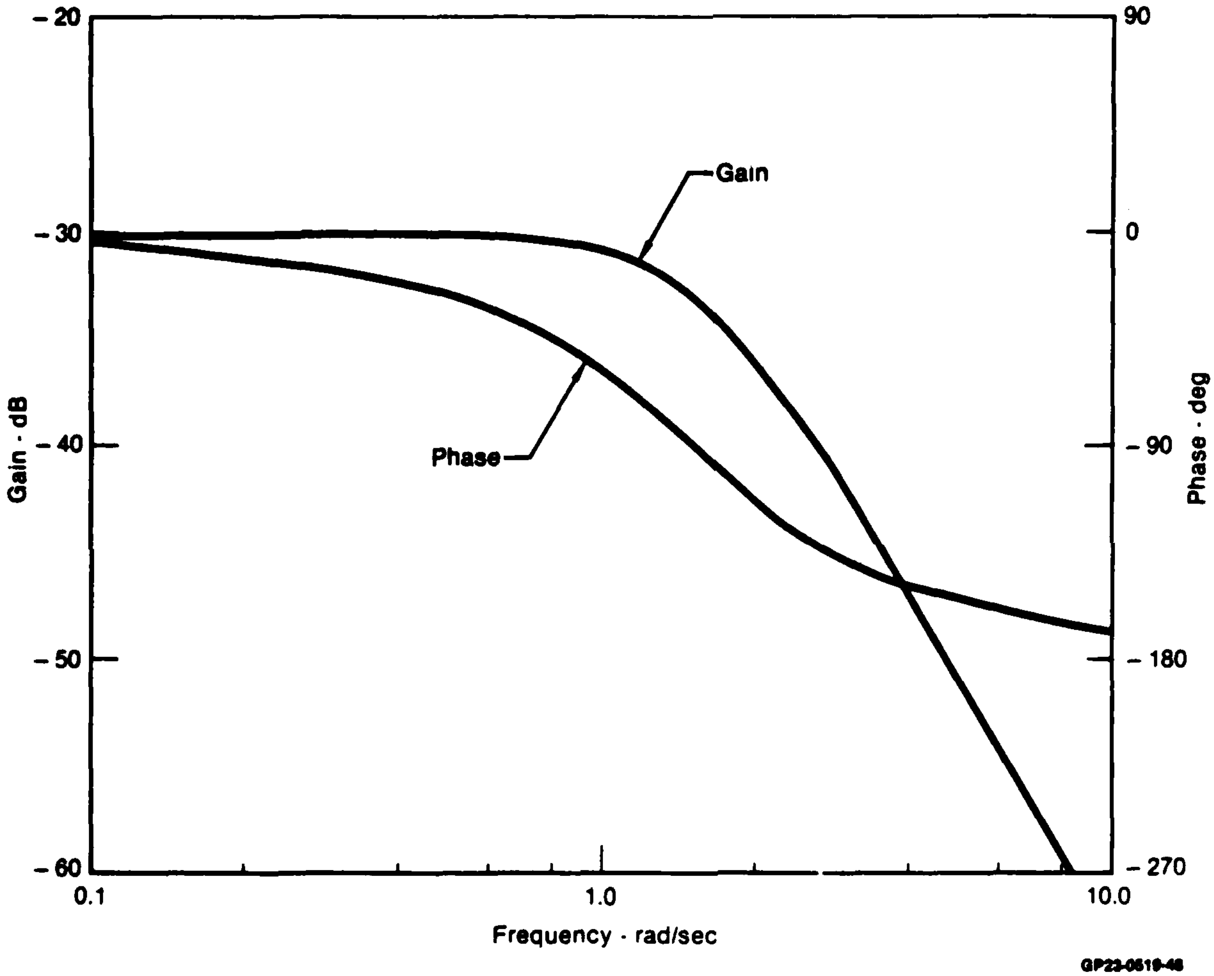

Figure A-2. Frequency and Time Response
Configuration TR1 [0.667; 1.5]

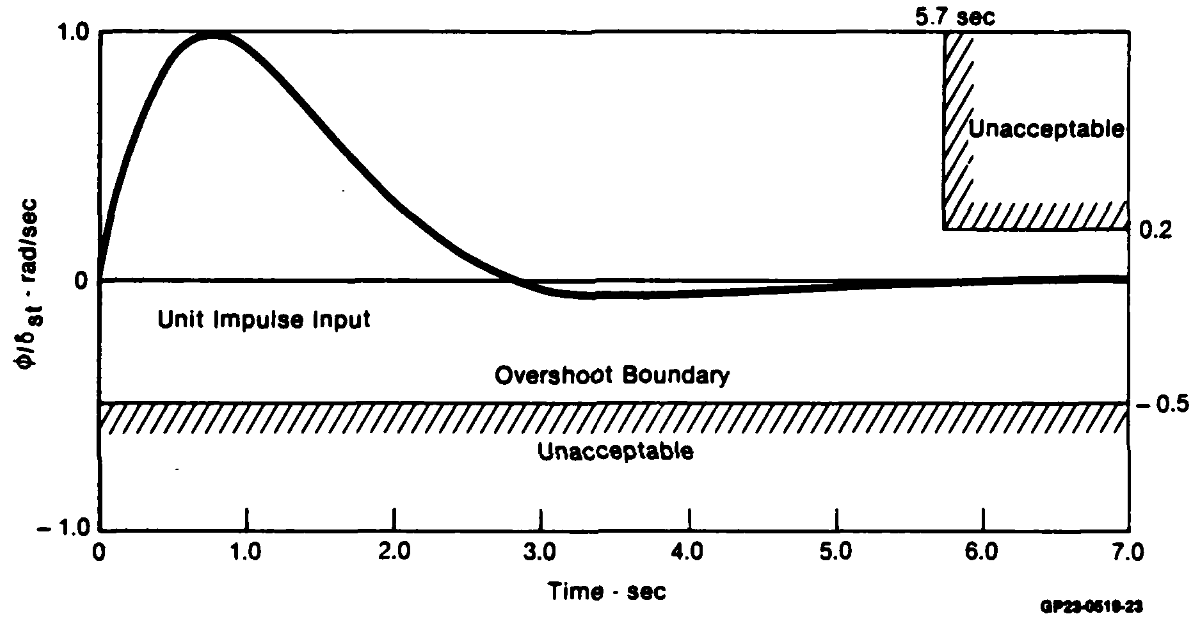

Figure A-2b. Frequency and Time Response

Configuration TR1 $\zeta = 0.667$ $\omega_n = 1.5$ rad/sec

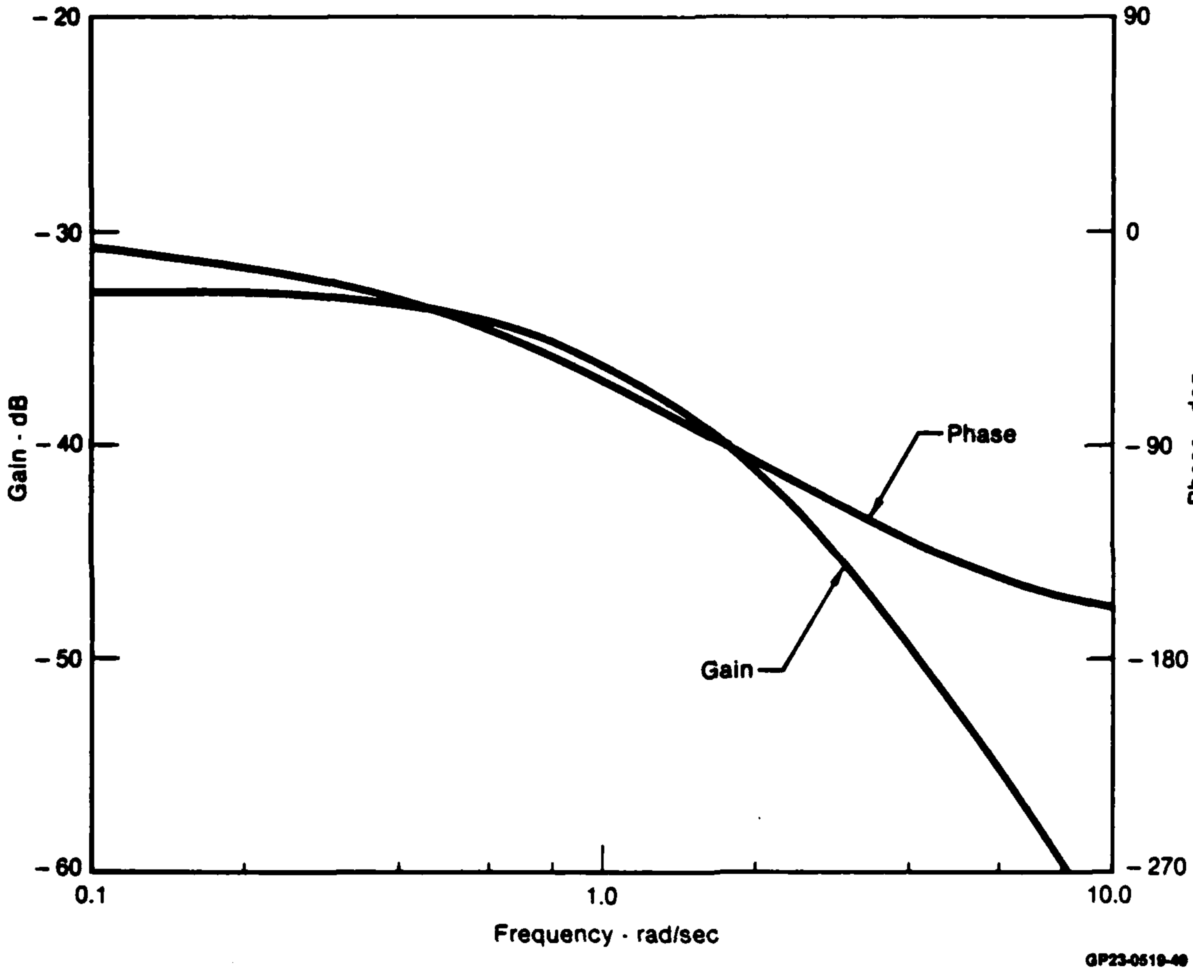

Figure A-3. Frequency and Time Response
Configuration TR2 [1.14; 1.75]

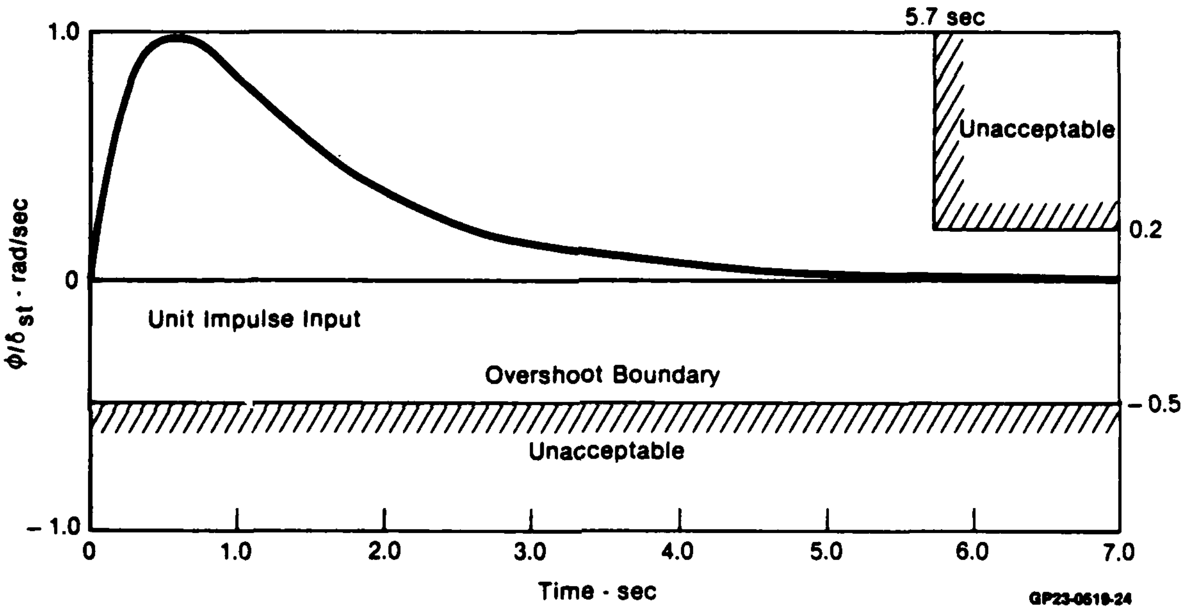

Figure A-3b. Frequency and Time Response
Configuration TR2 $\zeta = 1.14$ $\omega_n = 1.75$ rad/sec

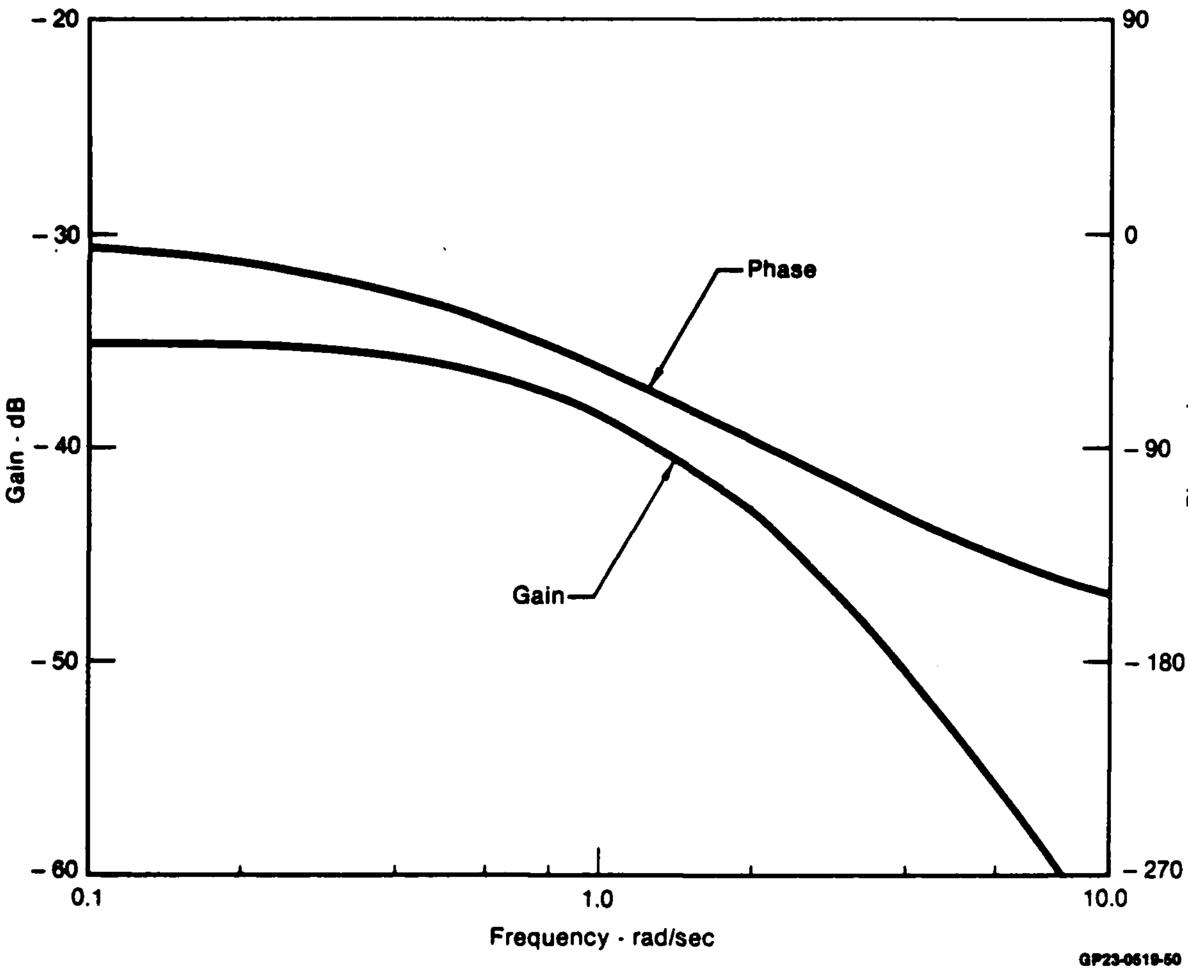

Figure A-4. Frequency and Time Response
Configuration TR3 [1.25; 2.0]

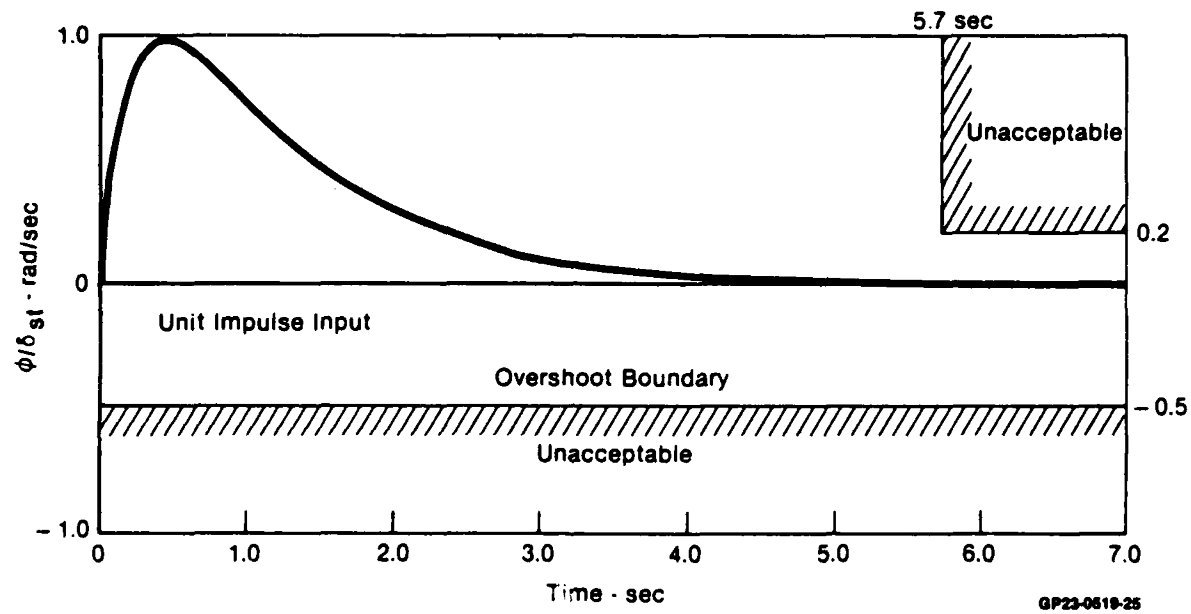

Figure A-4b. Frequency and Time Response
Configuration TR3 $\zeta = 1.25$ $\omega_n = 2.0$ rad/sec

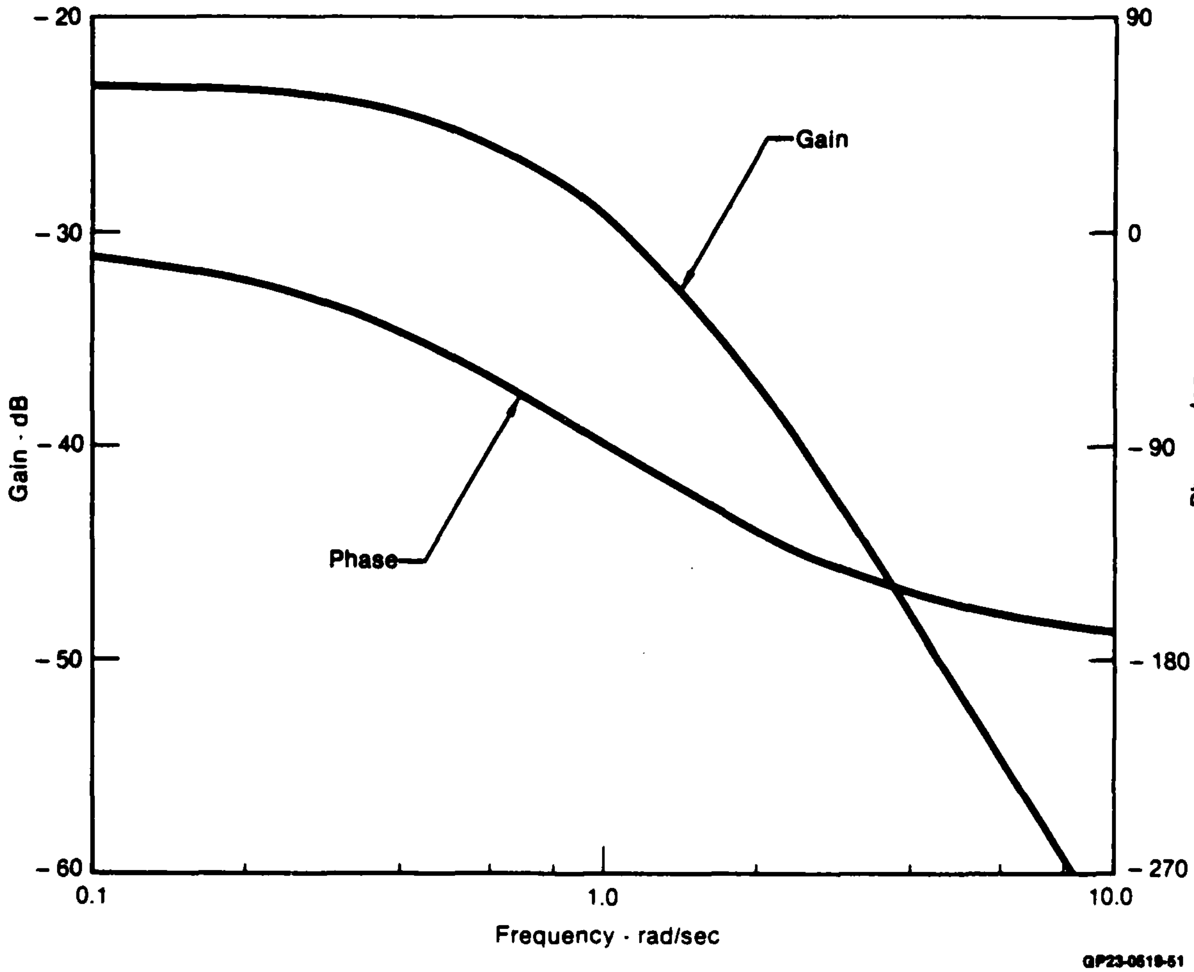

Figure A-5. Frequency and Time Response
Configuration TR4 [1.0; 1.0]

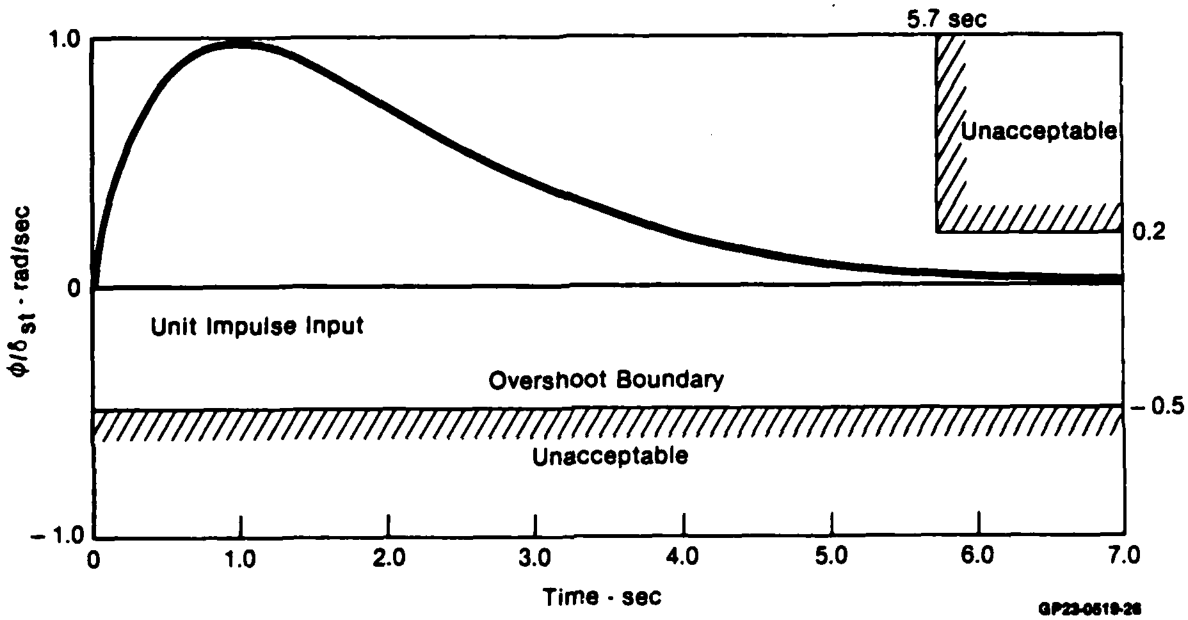

Figure A-5b. Frequency and Time Response
Configuration TR4 $\zeta = 1.0$ $\omega_n = 1.0$ rad/sec

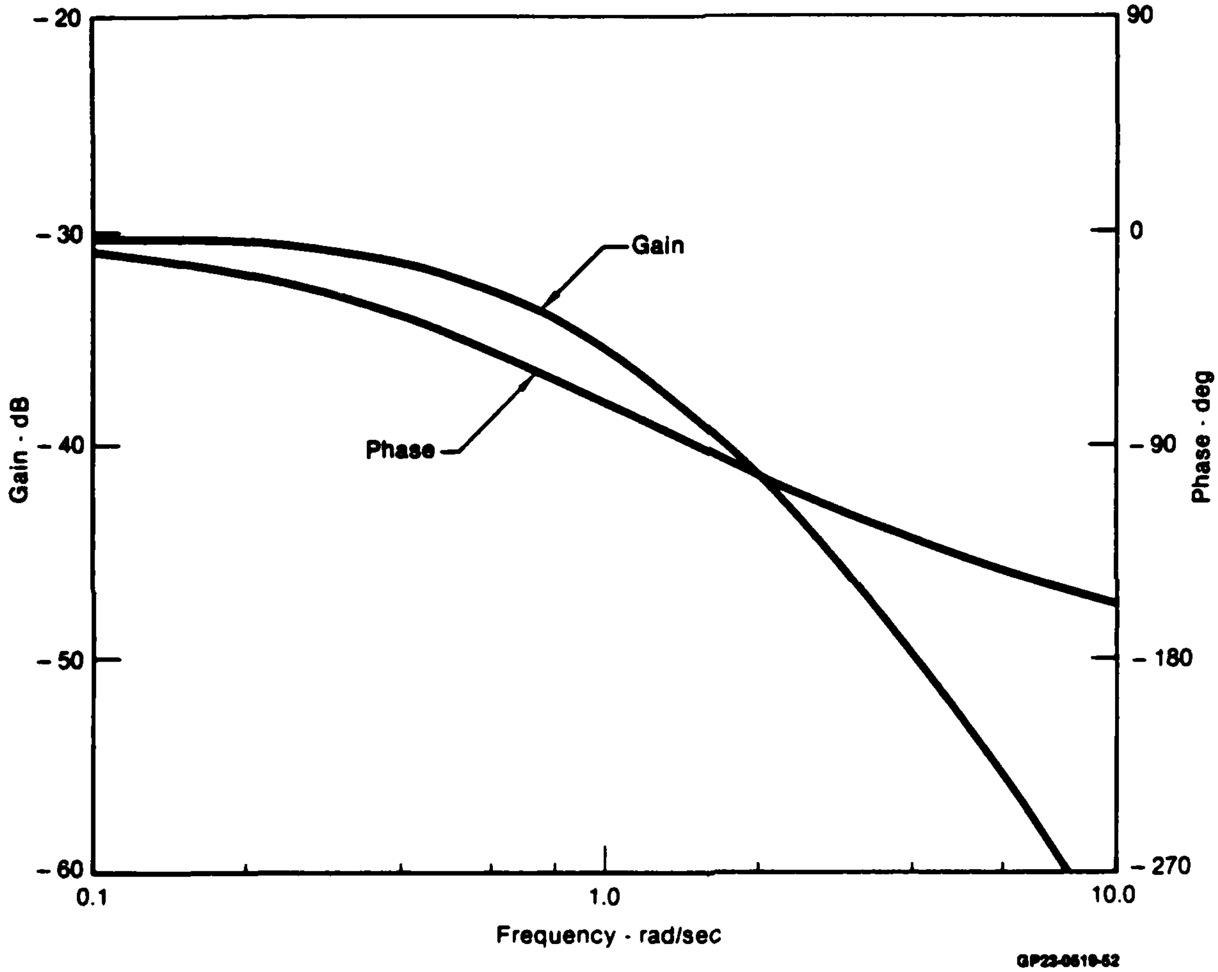

Figure A-6. Frequency and Time Response
Configuration TR5 [1.33; 1.5]

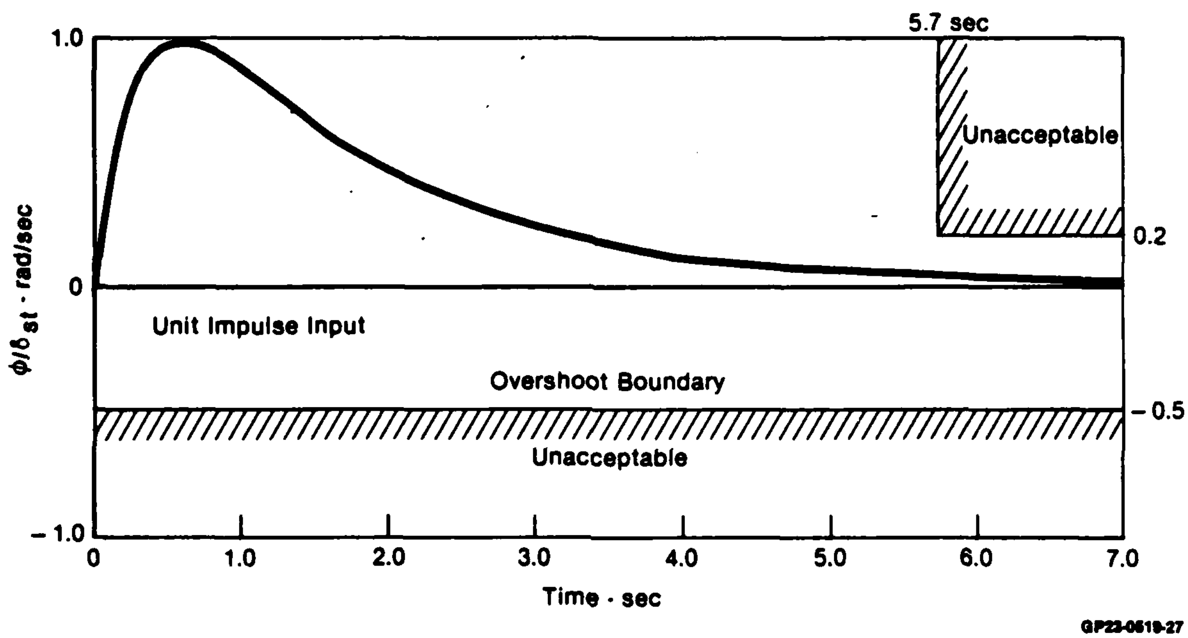

Figure A-6b. Frequency and Time Response
Configuration TR5 $\zeta = 1.33$ $\omega_n = 1.5$ rad/sec

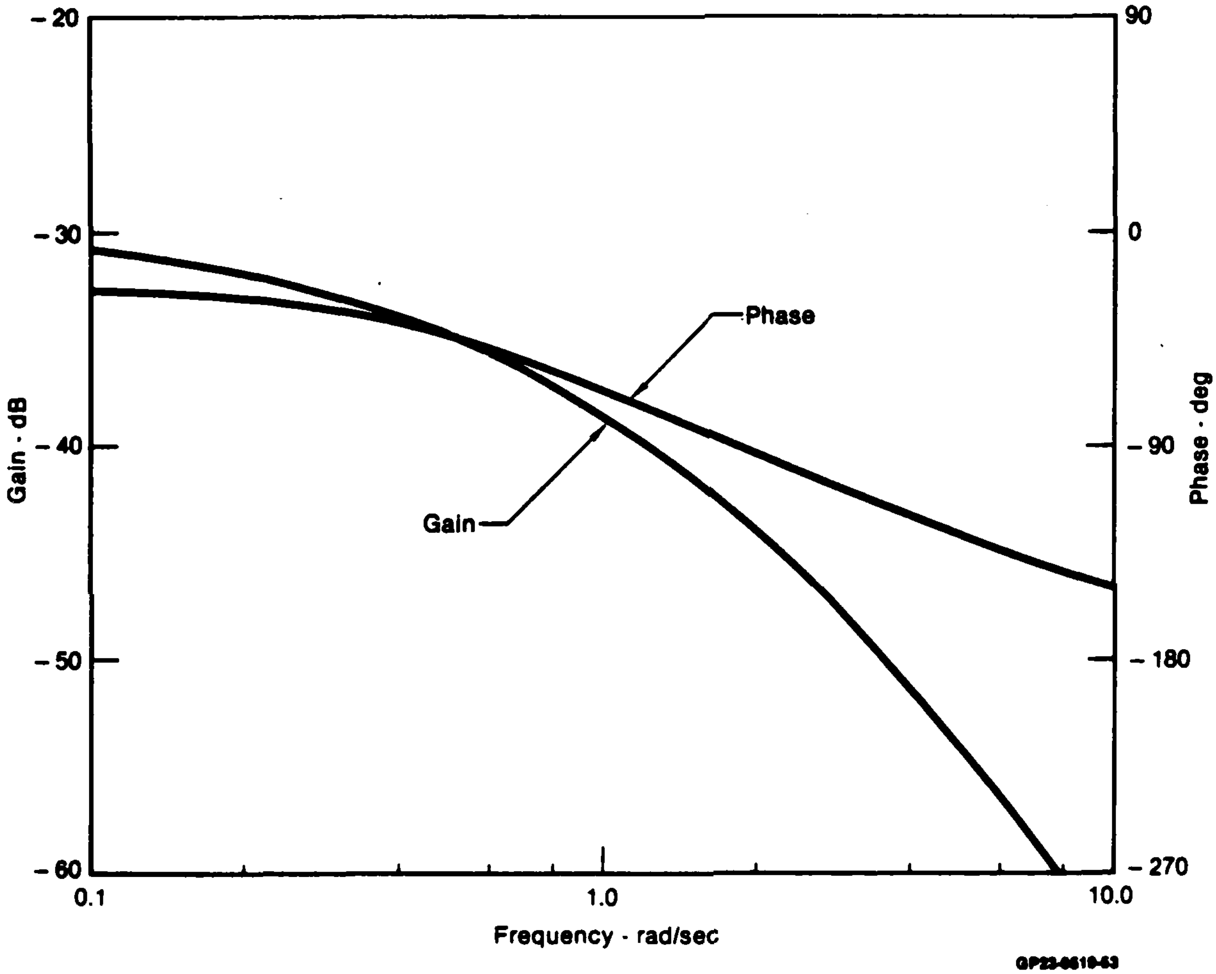

Figure A-7. Frequency and Time Response
Configuration TR6 [1.57; 1.75]

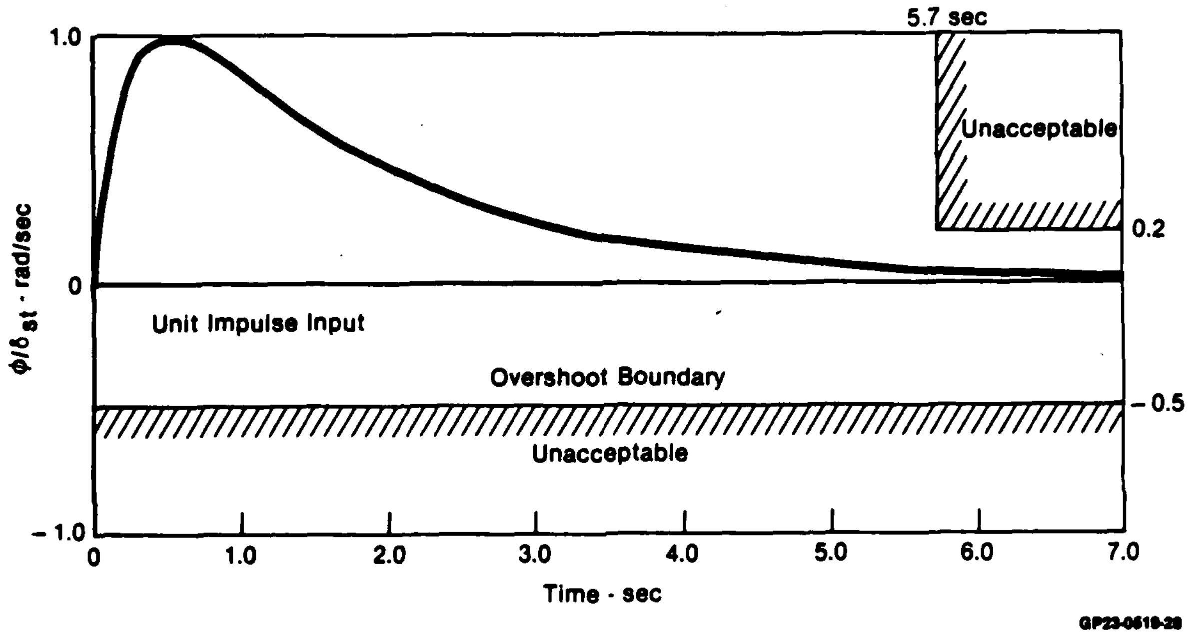

Figure A-7b. Frequency and Time Response
Configuration TR6 $\zeta = 1.57$ $\omega_n = 1.75$ rad/sec

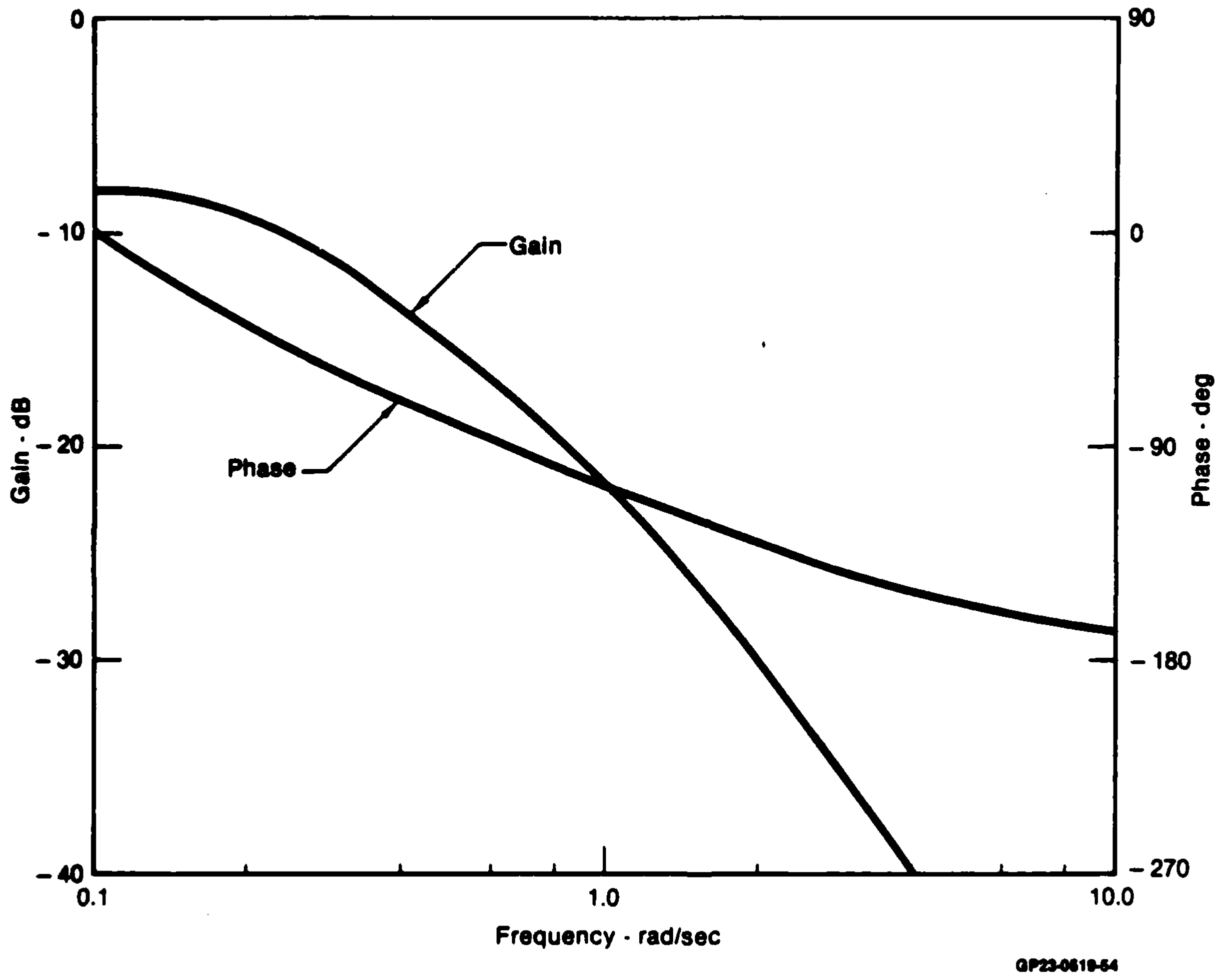

Figure A-8. Frequency and Time Response
Configuration TR7 [2.0; 0.5]   1/T = 0.01   λ = 0.1

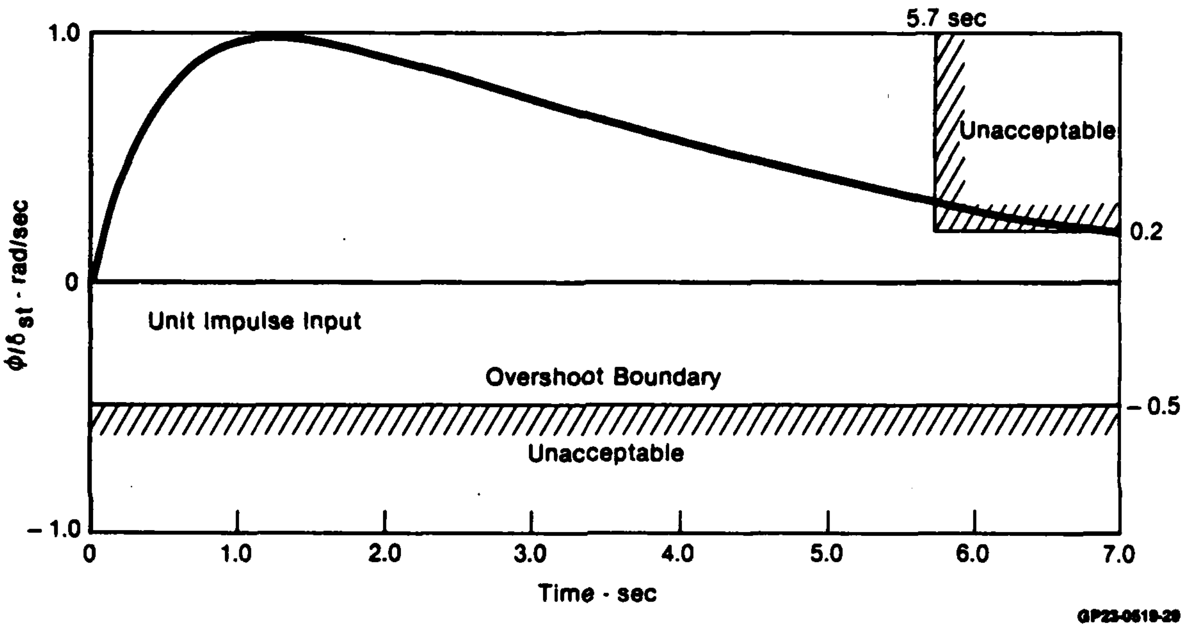

Figure A-8b. Frequency and Time Response
Configuration TR7 $\zeta = 2.0$ $\omega_n = 0.5$ rad/sec
$1/T = 0.01$ rad/sec $\lambda = 0.1$ rad/sec

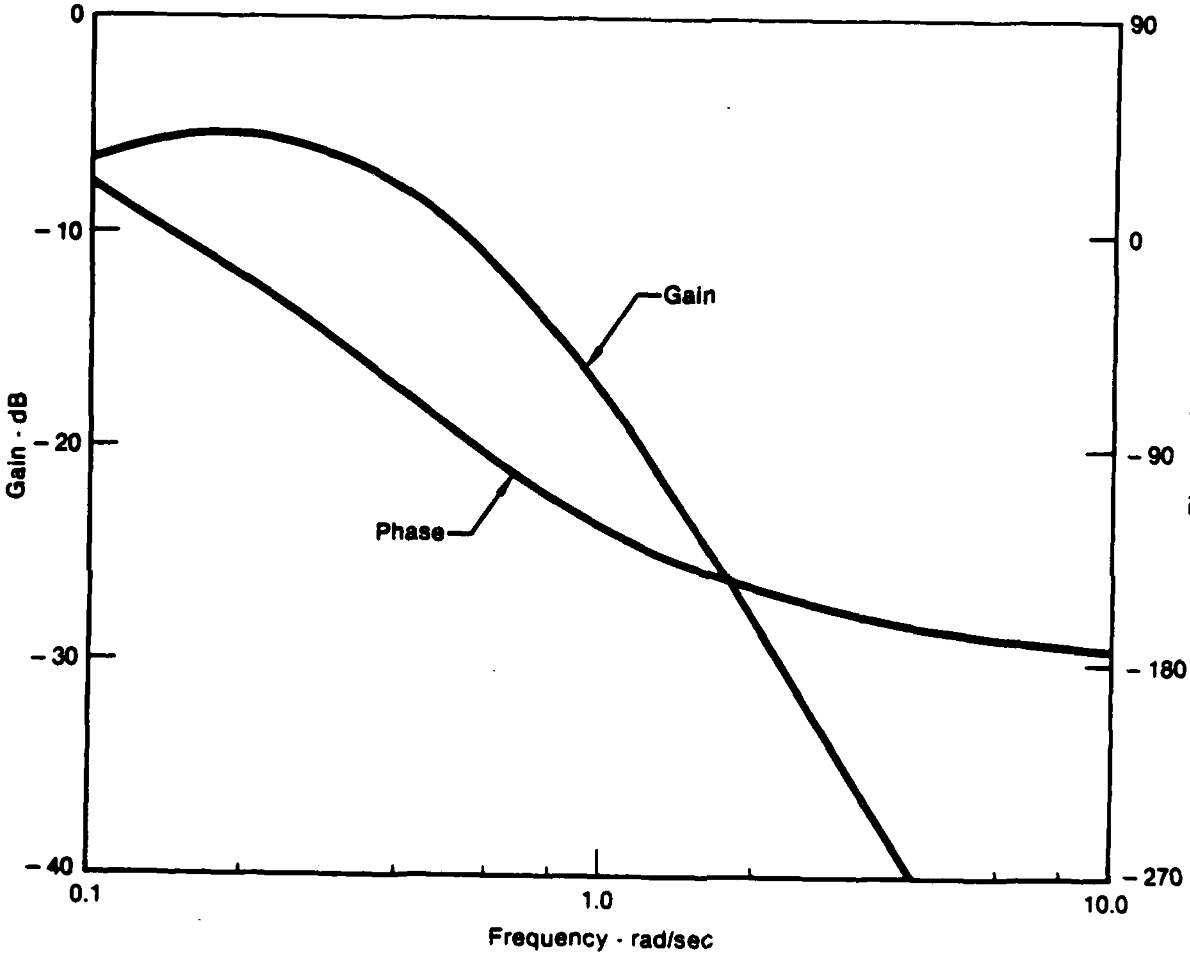

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Figure A-9. Frequency and Time Response
Configuration TR8 [1.0; 0.5] 1/T = 0.01 λ = 0.1

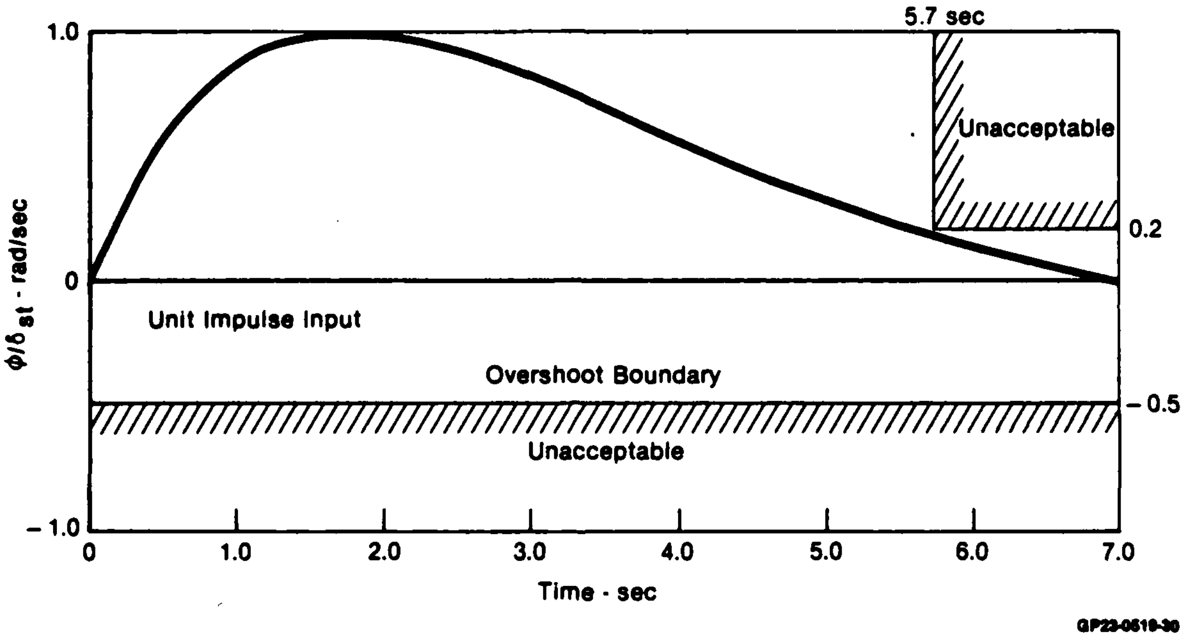

Figure A-9b. Frequency and Time Response
Configuration TR8 $\zeta = 1.0$ $\omega_n = 0.5$ rad/sec
$1/T = 0.1$ rad/sec $\lambda = 0.1$ rad/sec

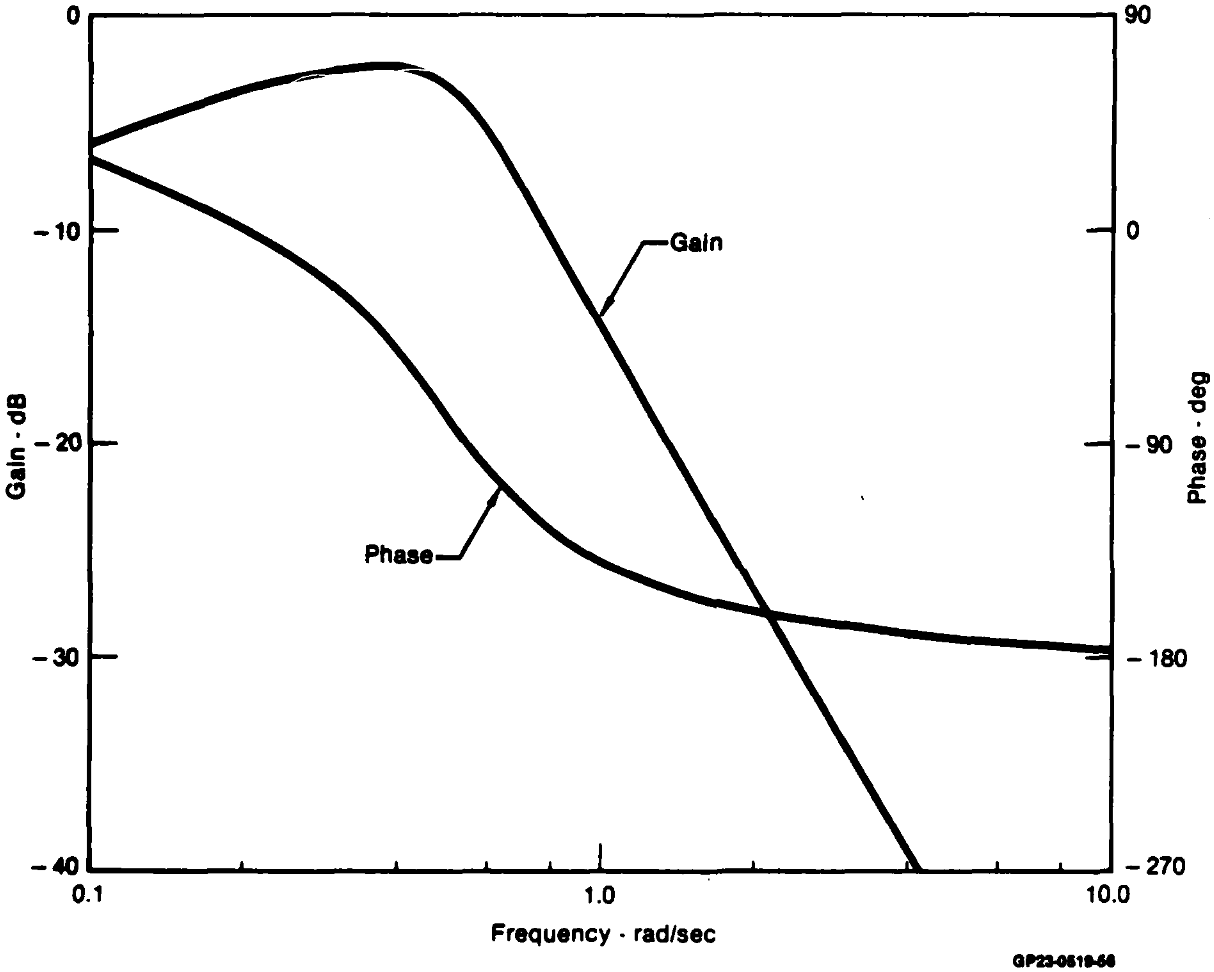

Figure A-10. Frequency and Time Response
Configuration TR9 [0.5; 0.5] 1/T = 0.1 λ = 0.1

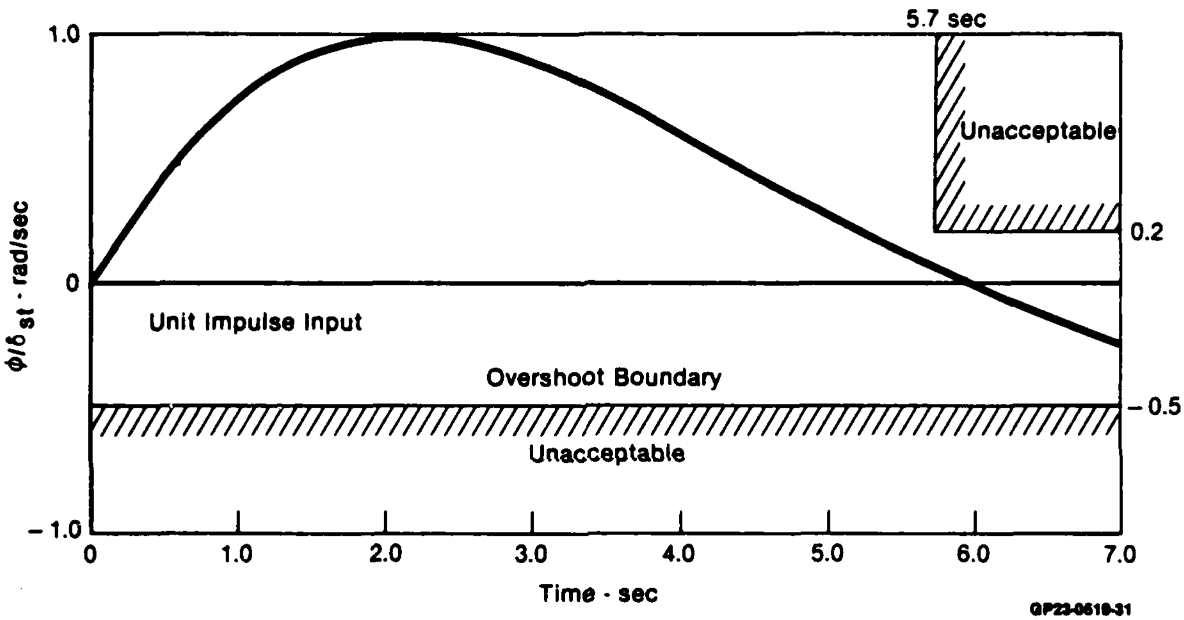

Figure A-10b. Frequency and Time Response
Configuration TR9 $\zeta = 0.5$ $\omega_n = 0.5$ rad/sec
$1/T = 0.1$ rad/sec $\lambda = 0.1$ rad/sec

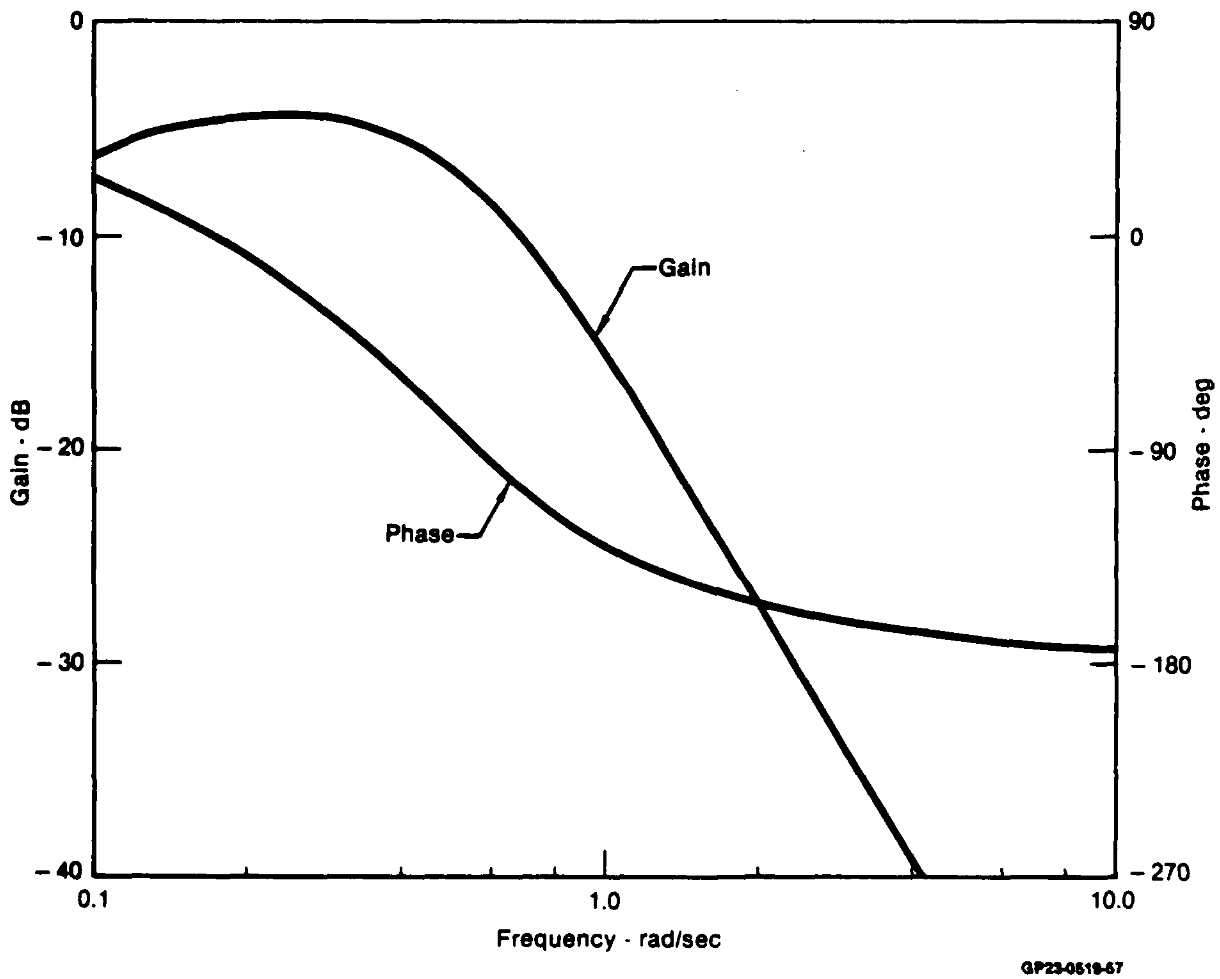

Figure A-11. Frequency and Time Response
Configuration TR10 [0.75; 0.5] 1/T = 0.01 λ = 0.1

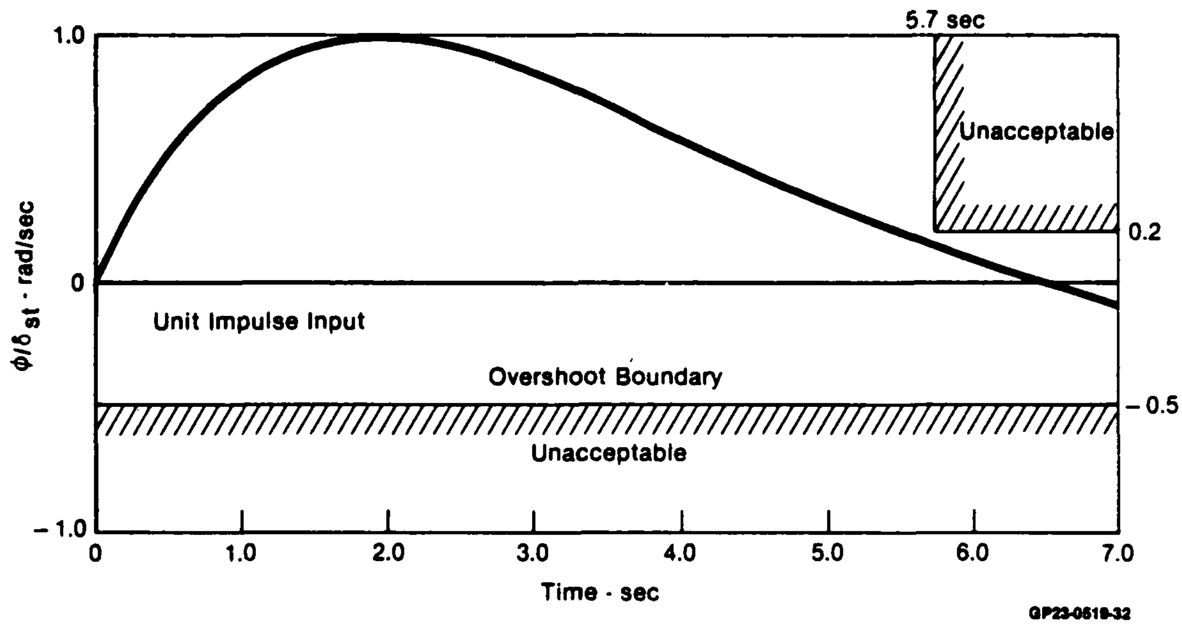

Figure A-11b. Frequency and Time Response
Configuration TR10 $\zeta = 0.75$ $\omega_n = 0.5$ rad/sec
$1/T = 0.01$ rad/sec $\lambda = 0.1$ rad/sec

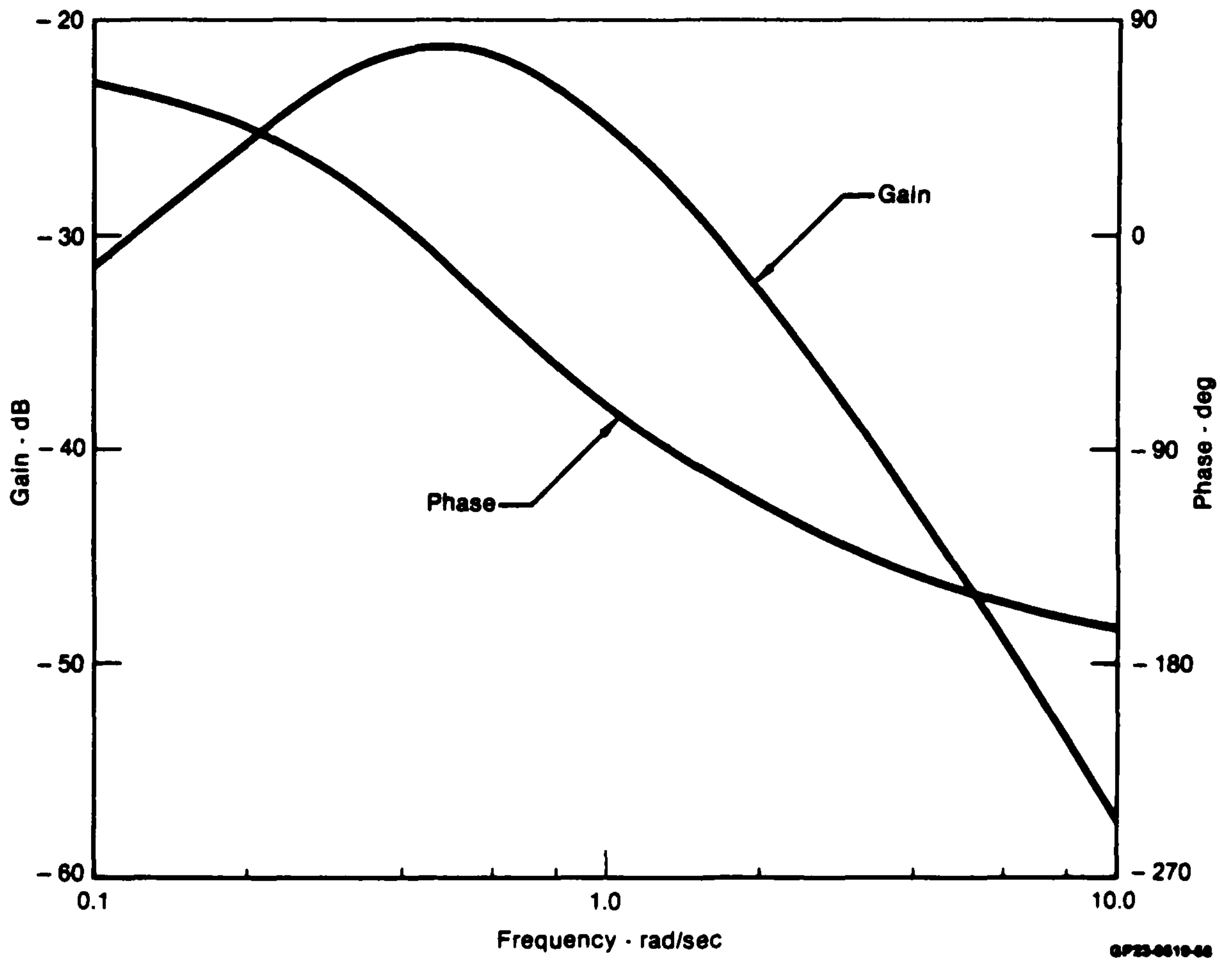

Figure A-11c. Frequency and Time Response
Configuration TR10 [0.75; 0.5]   1/T = 0.01   λ = 2.0

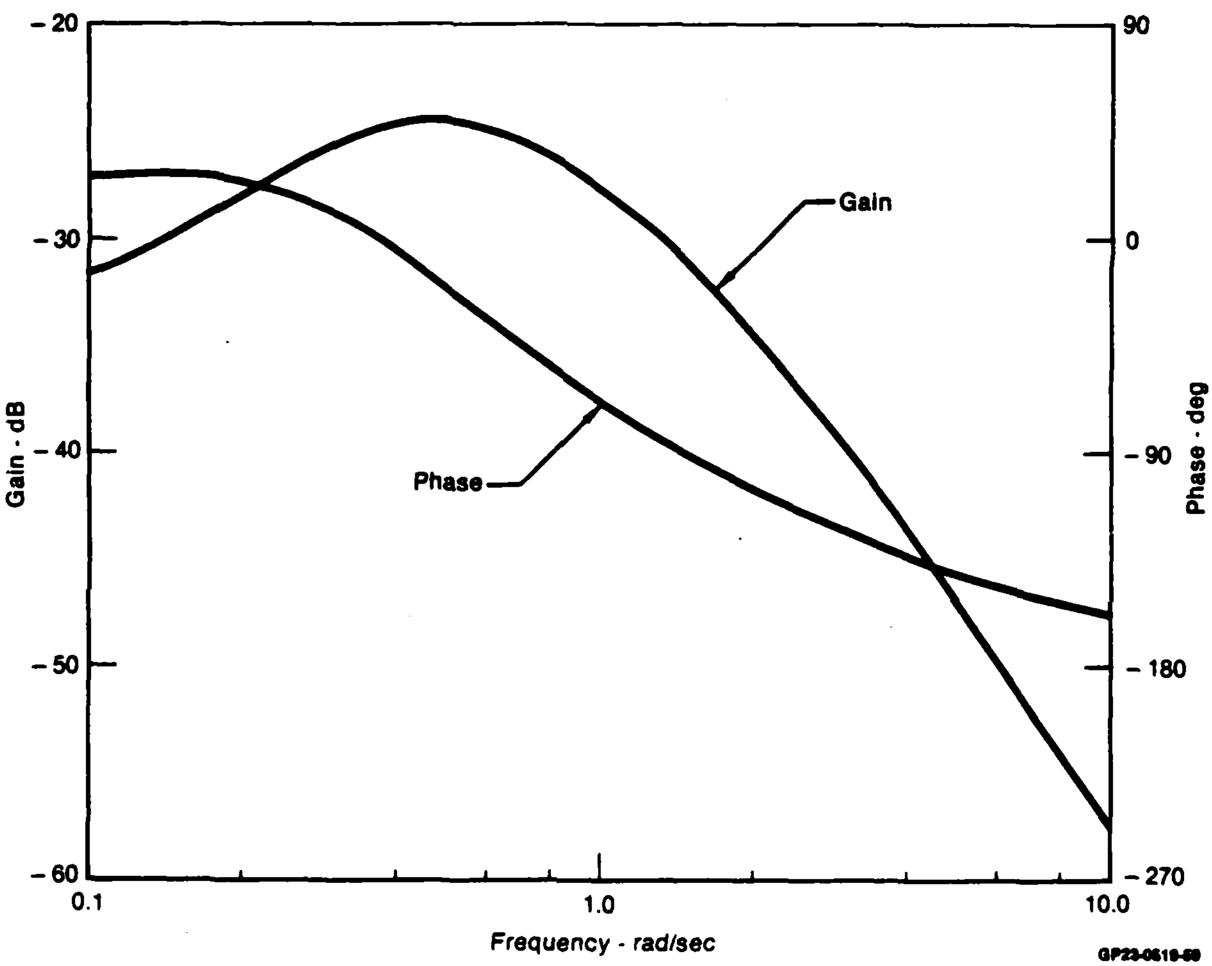

Figure A-11d. Frequency and Time Response

Configuration TR10 [0.75; 0.5] $1/T = 0.01$ $\lambda = 3.0$

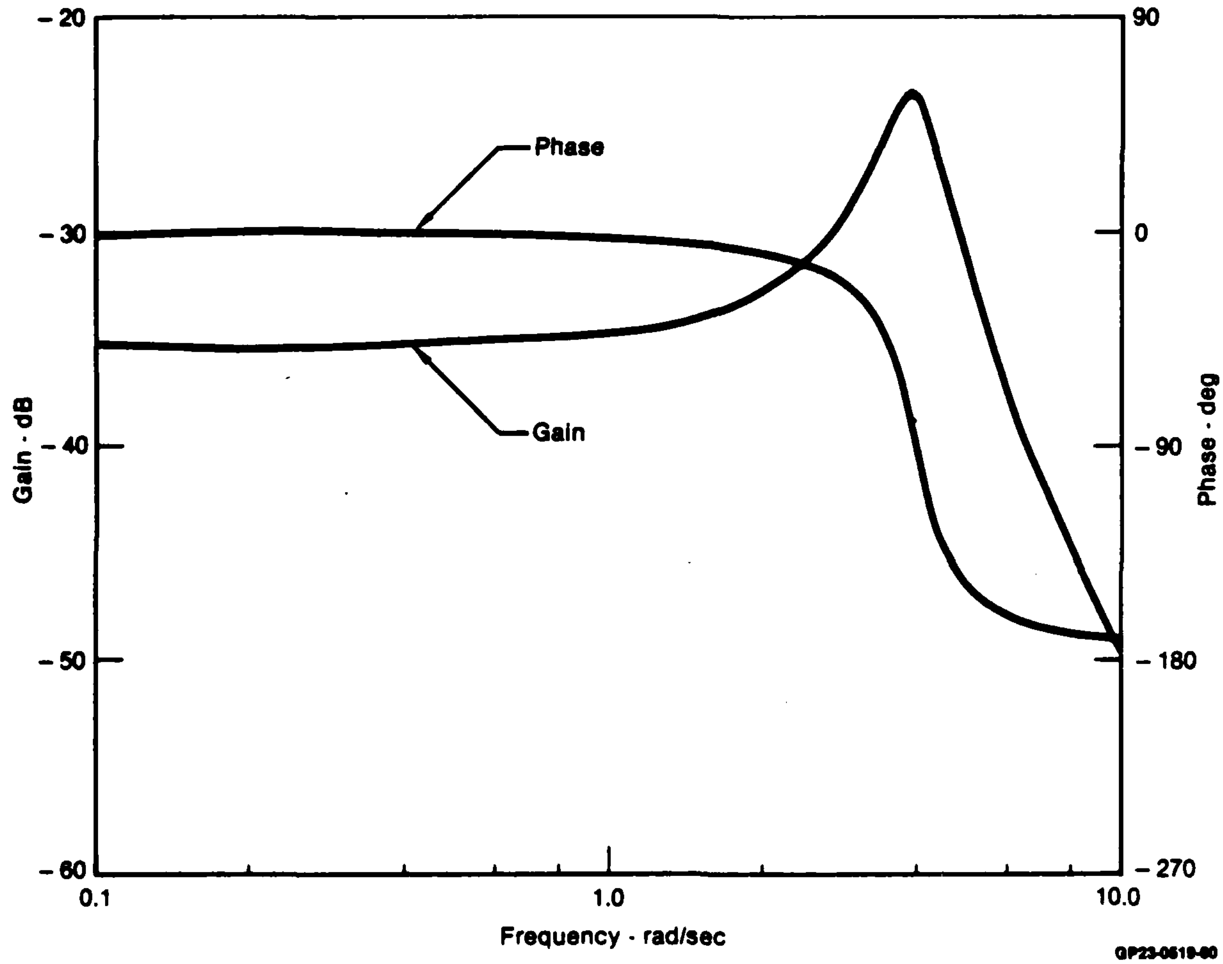

Figure A-12. Frequency and Time Response
Configuration TR11 [0.125; 4.0]

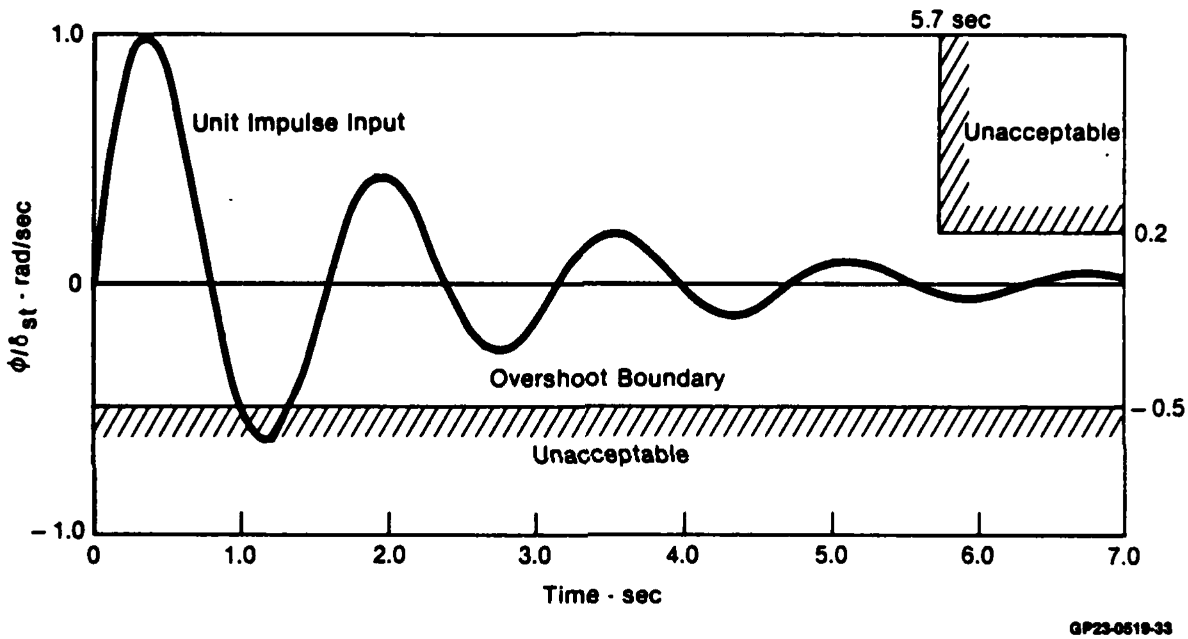

Figure A-12b. Frequency and Time Response
Configuration TR11 $\zeta = 0.125$ $\omega_n = 4.0$ rad/sec

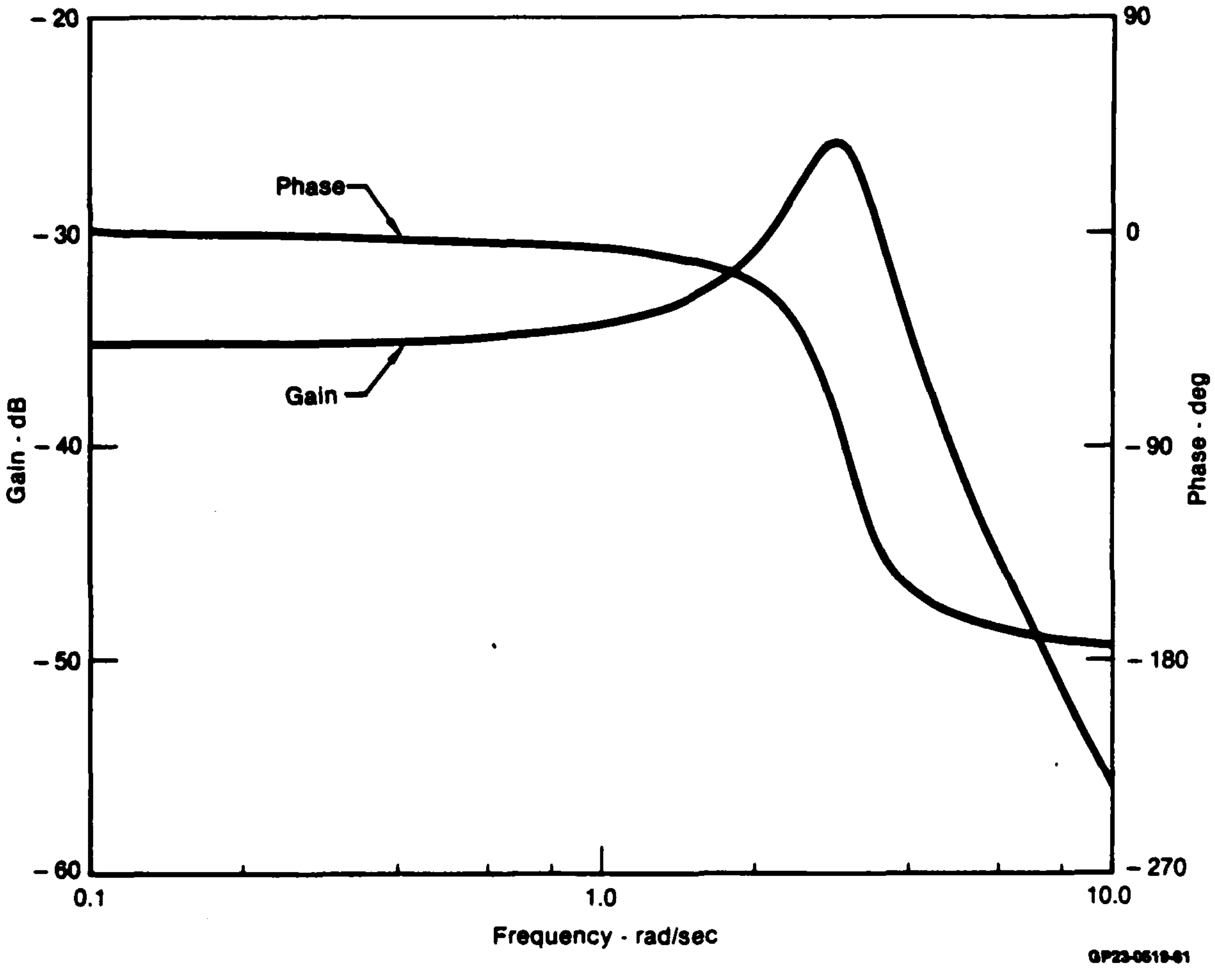

Figure A-13. Frequency and Time Response
Configuration TR12 [0.167; 3.0]

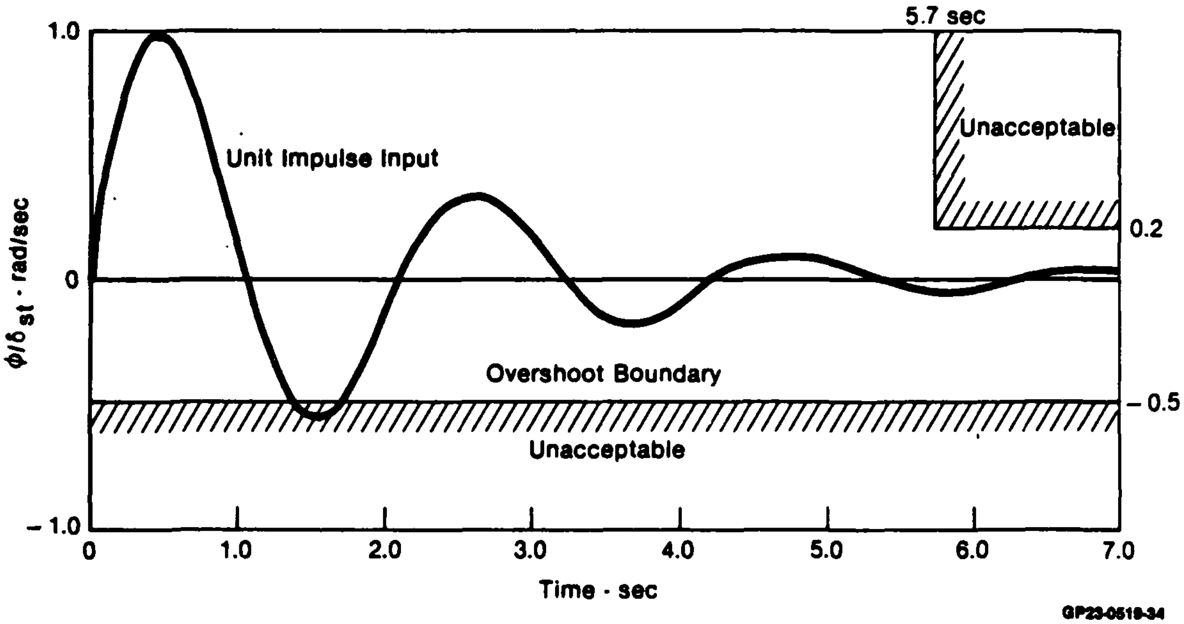

Figure A-13b. Frequency and Time Response

Configuration TR12 $\zeta = 0.167$ $\omega_n = 3.0$ rad/sec

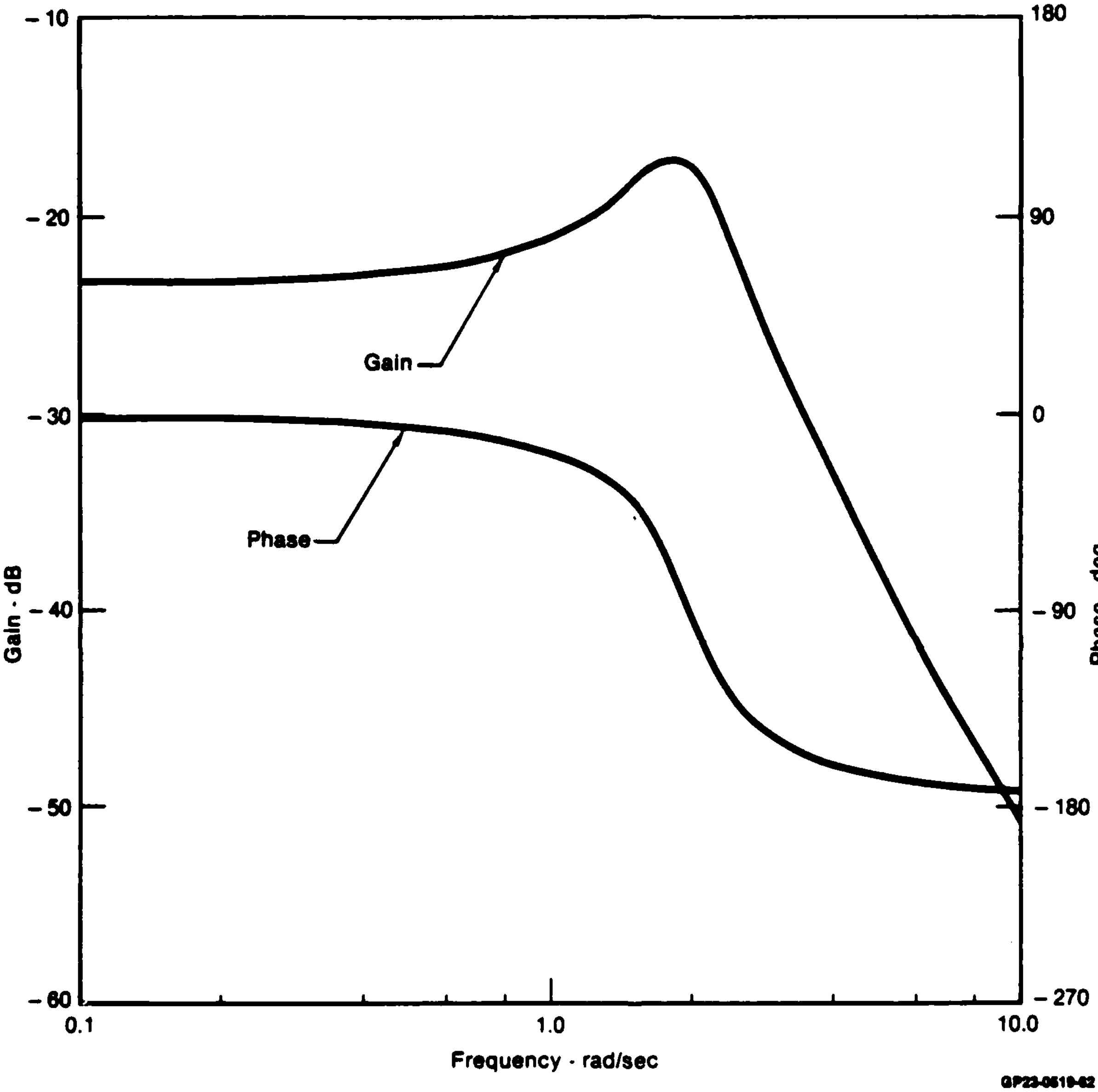

Figure A-14. Frequency and Time Response
Configuration TR13 [0.25; 2.0]

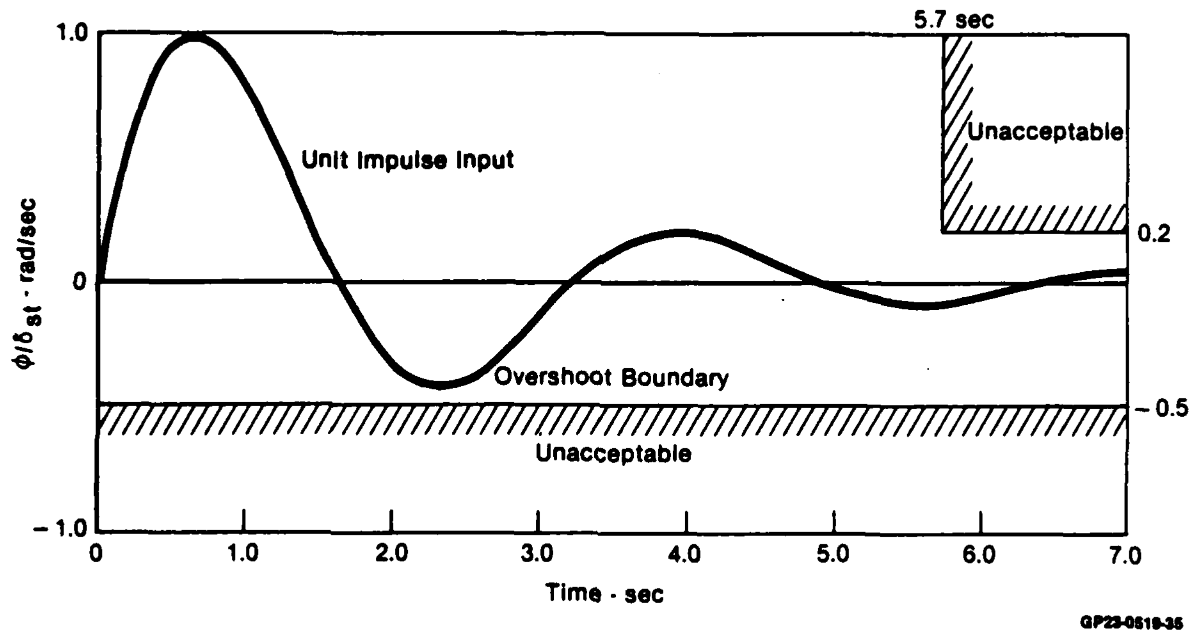

Figure A-14b. Frequency and Time Response
Configuration TR13 $\zeta = 0.25$ $\omega_n = 2.0$ rad/sec

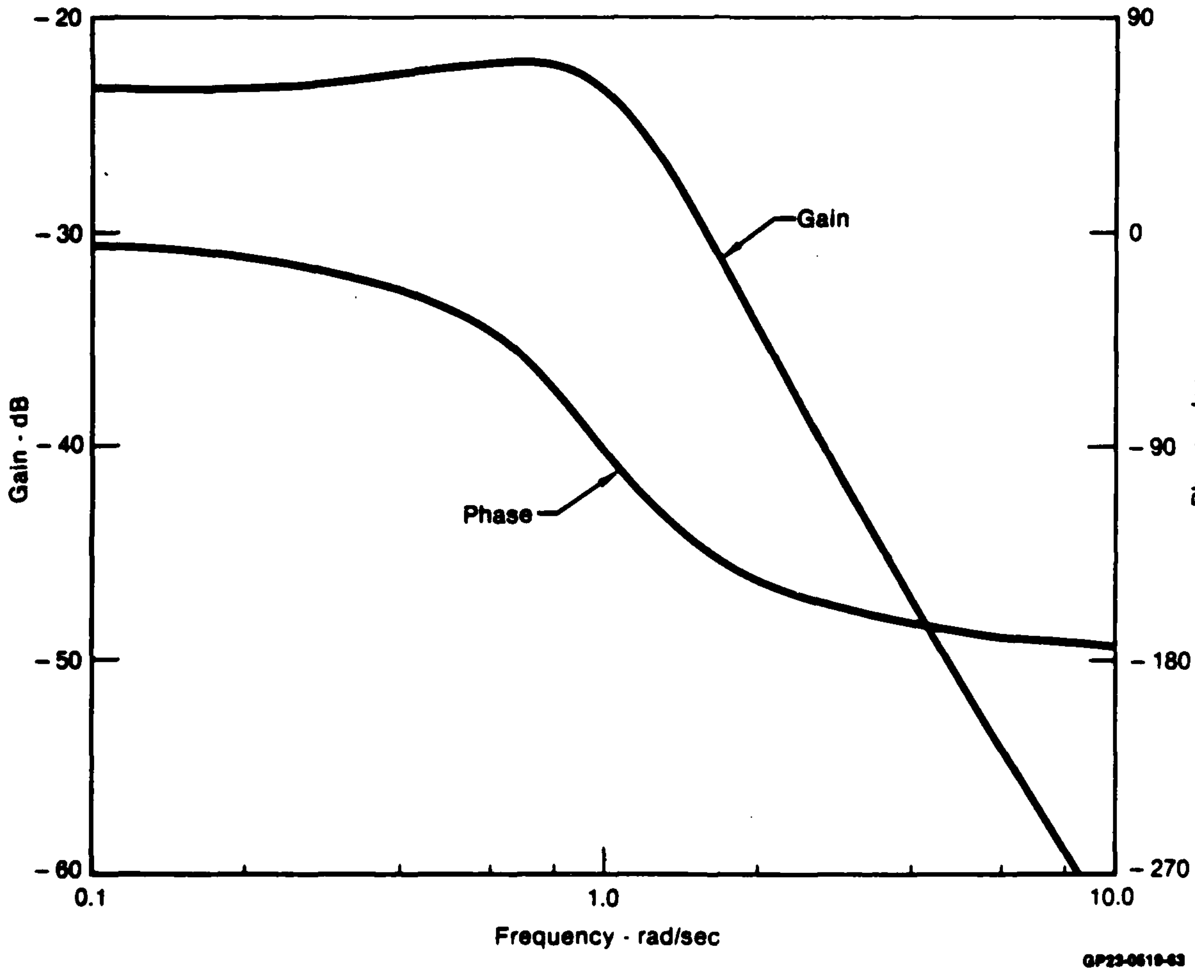

Figure A-15. Frequency and Time Response
Configuration TR14 [0.5; 1.0]

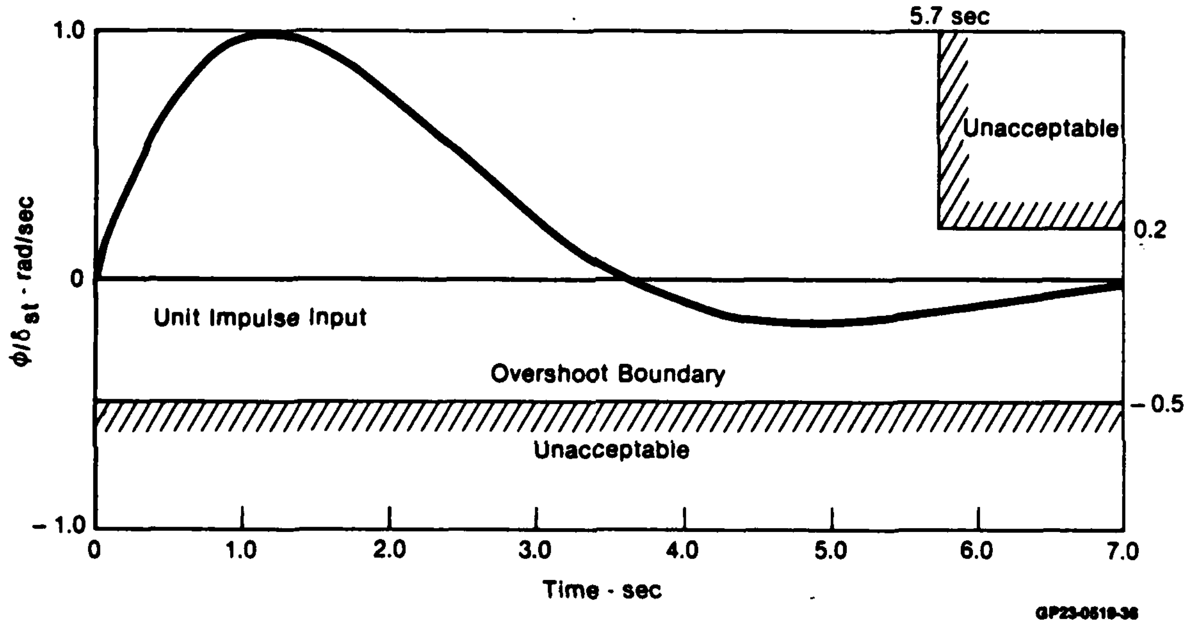

Figure A-15b. Frequency and Time Response

Configuration TR14 $\zeta = 0.5$ $\omega_n = 1.0$ rad/sec

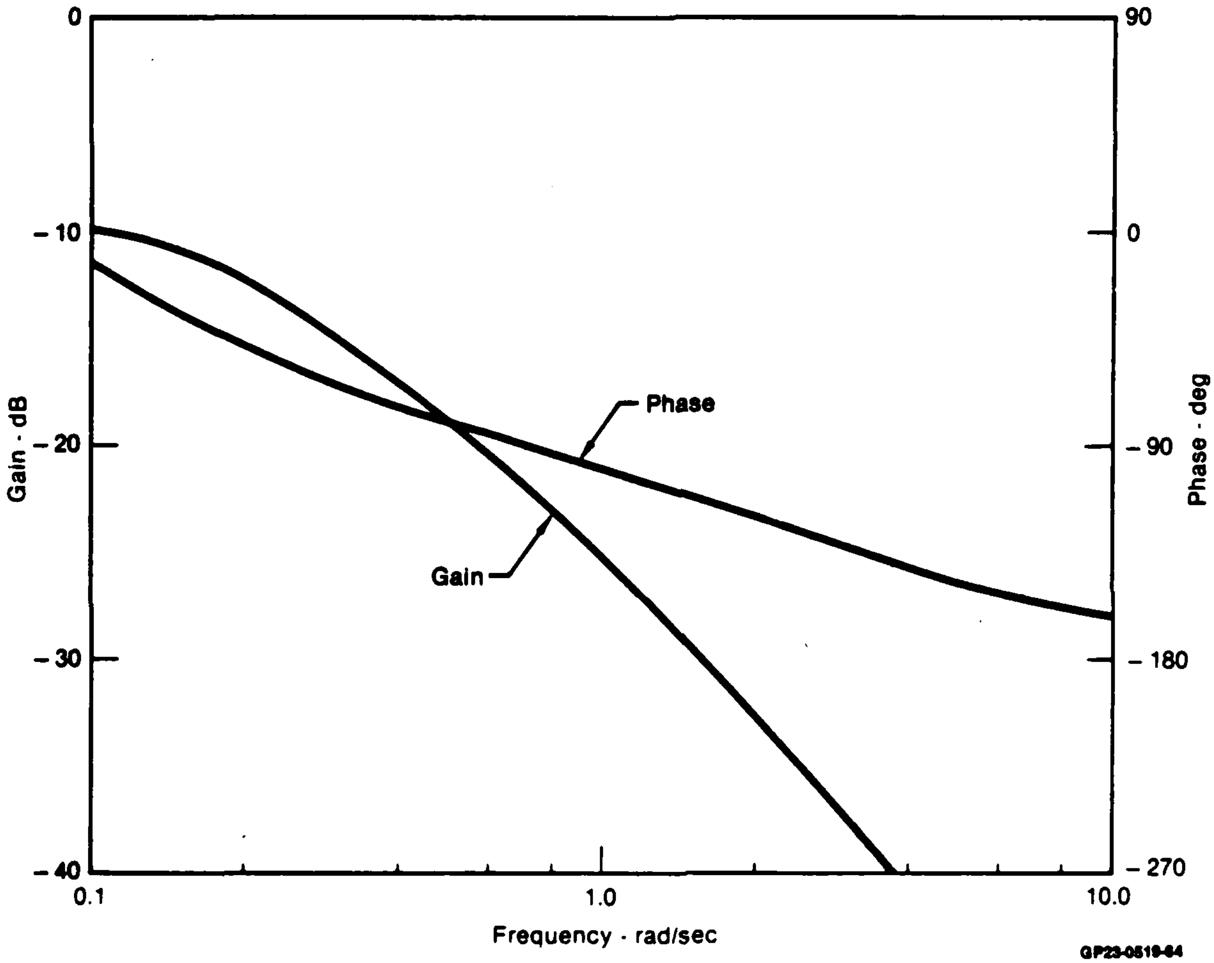

Figure A-16. Frequency and Time Response
Configuration TR15 [3.0; 0.5] 1/T = 0.01 λ = 0.1

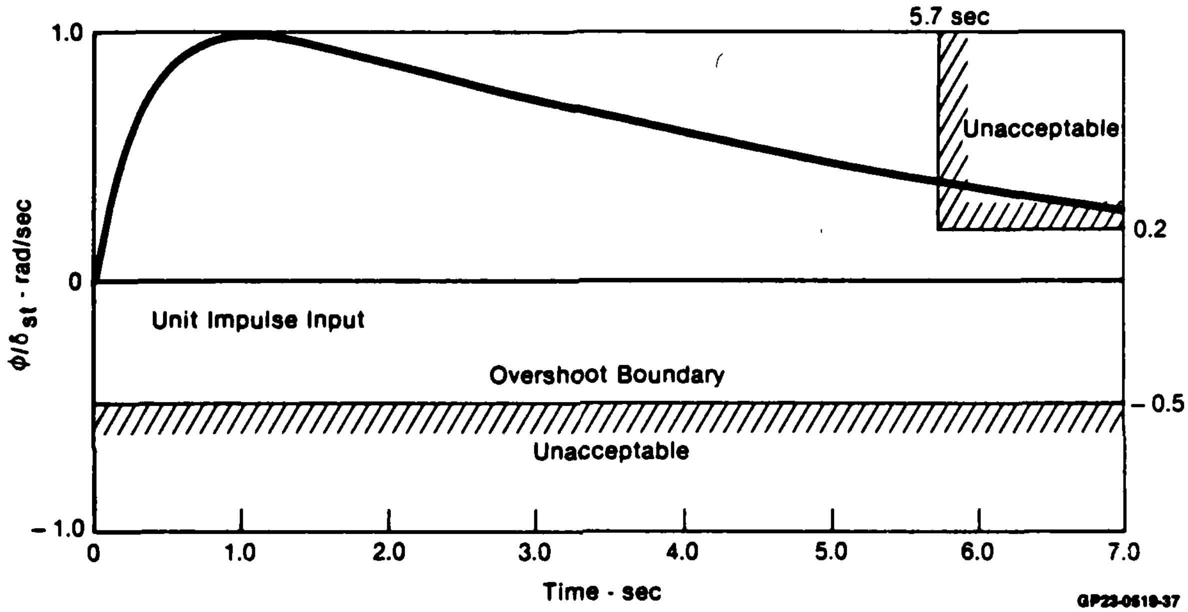

Figure A-16b. Frequency and Time Response
Configuration TR15 $\zeta = 3.0$ $\omega_n = 0.5$ rad/sec
$1/T = 0.01$ rad/sec $\lambda = 0.1$ rad/sec

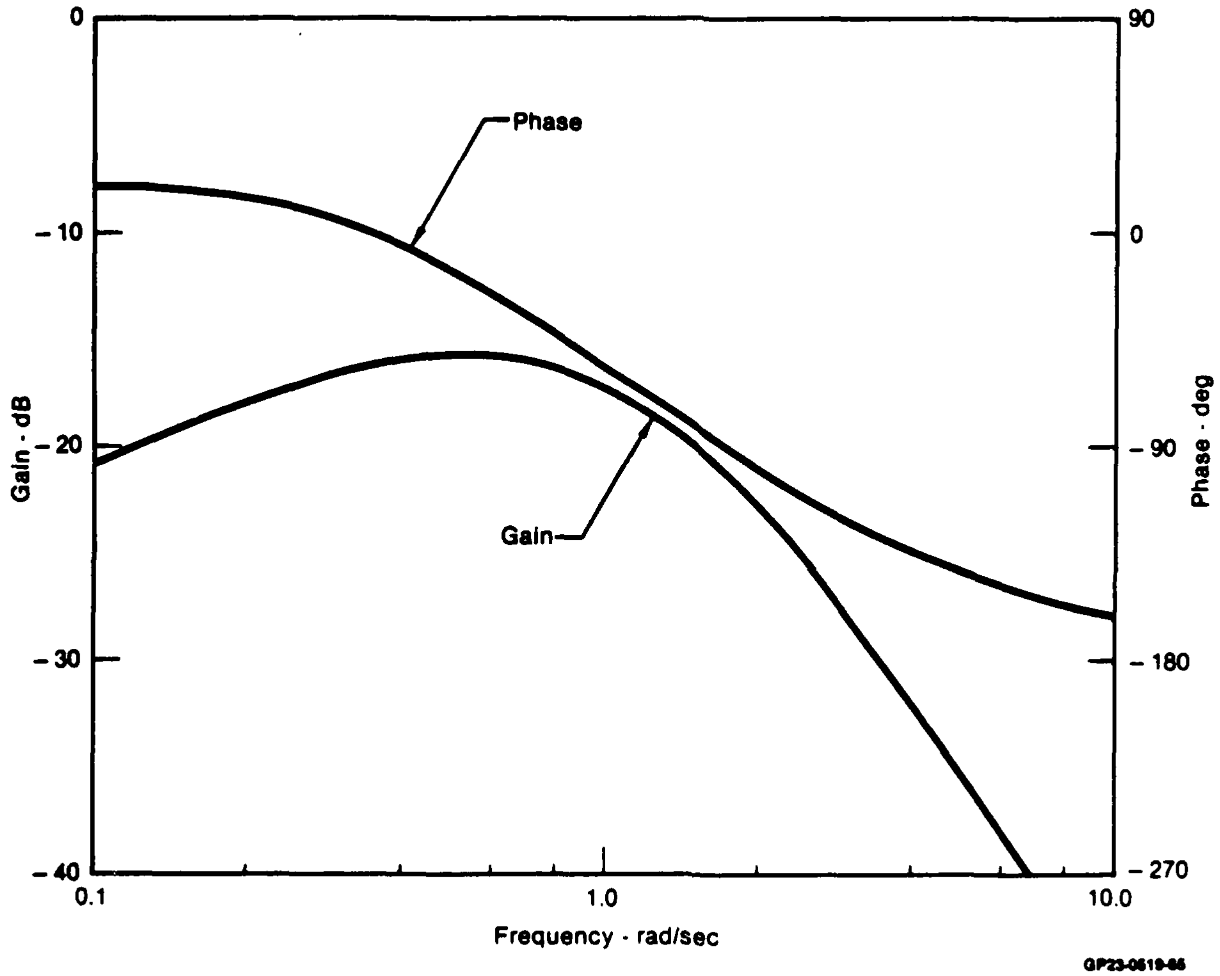

Figure A-17. Frequency and Time Response
Configuration TR16 [1.0; 1.5] 1/T = 0.01 λ = 0.3

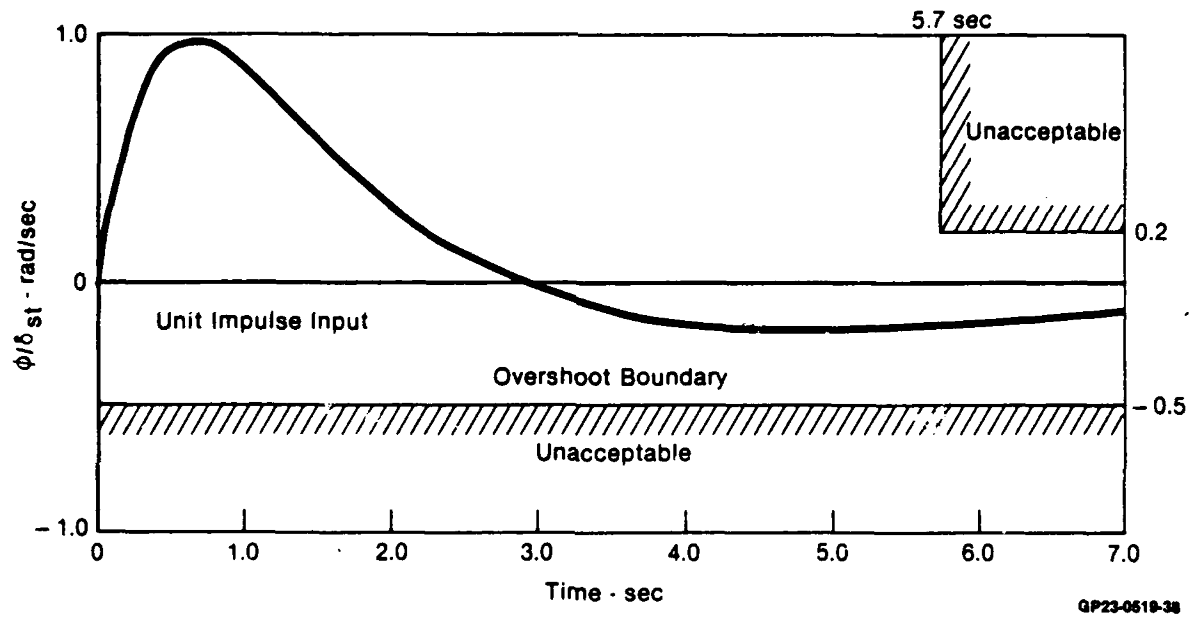

Figure A-17b. Frequency and Time Response
Configuration TR16 $\zeta = 1.0$ $\omega_n = 1.5$ rad/sec
$1/T = 0.1$ rad/sec $\lambda = 0.3$ rad/sec

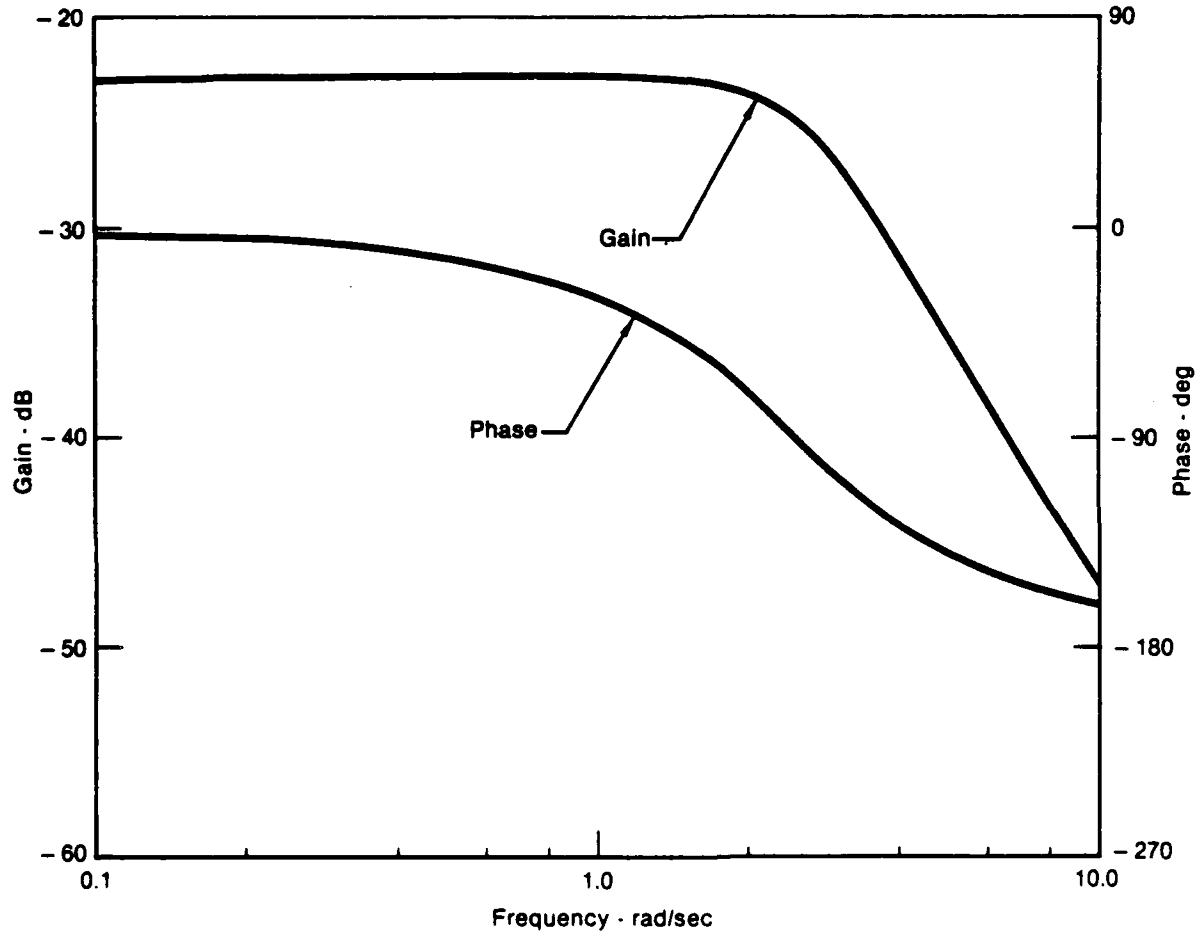

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Figure A-18. Frequency and Time Response
Configuration TR17 [0.6; 2.5]

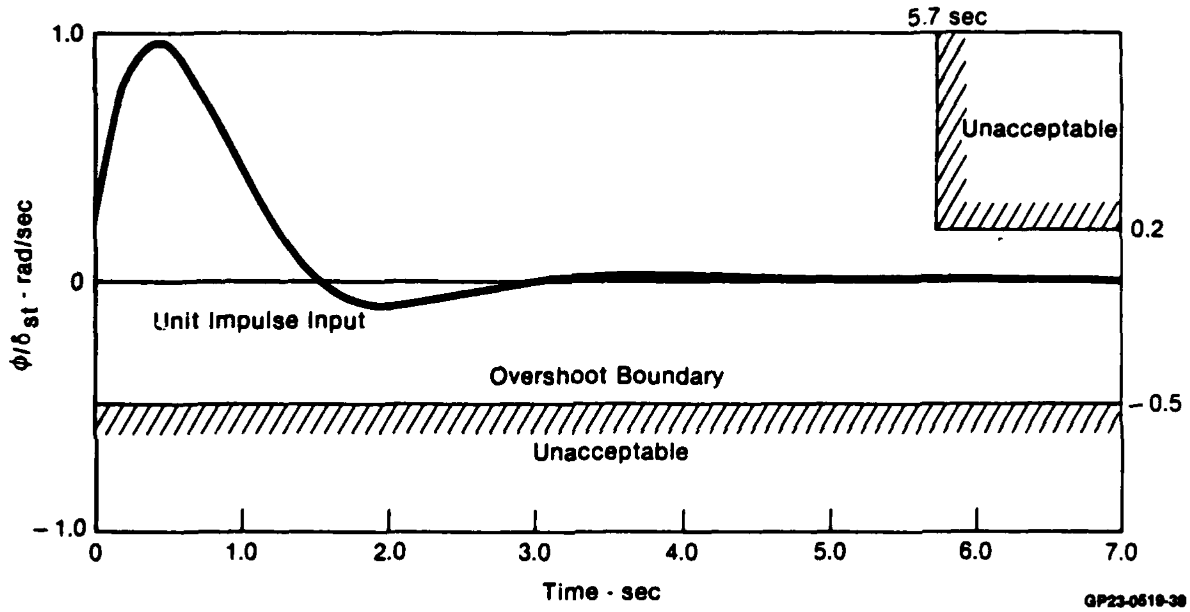

Figure A-18b. Frequency and Time Response
Configuration TR17 $\zeta = 0.6$ $\omega_n = 2.5$ rad/sec

Configuration	K rad/sec^2/cm	K_{ss} rad/cm	ζ	ω_n rad/sec	λ rad/sec	1/T rad/sec	Pilot Rating A	Pilot Rating B	Pilot Rating C
TR1	0.069	0.031	0.667	1.5	—	—	7, 4	3, 7	6. 5
	0.309	0.137	↓	↓	—	—	3, 3		
	0.387	0.172	↓	↓	—	—	6, 6		
TR2	0.069	0.023	1.14	1.75	—	—	4, 7	4	5
	0.105	0.034	↓	↓	—	—	5		
	0.211	0.069	↓	↓	—	—	5		
	0.421	0.137	↓	↓	—	—	8, 3		
	0.919	0.300	↓	↓	—	—	3		
TR3	0.069	0.017	1.25	2.0	—	—	5, 4	3, 7	4
	0.137	0.034	↓	↓	—	—	4, 3		
	0.276	0.069	↓	↓	—	—	3, 4		
TR4	0.069	0.069	1.0	1.0	—	—	5, 6	6, 7	
	0.137	0.137	↓	↓	—	—	4, 6, 5		
	0.275	0.275	↓	↓	—	—	5, 6		
	0.034	0.034	↓	↓	—	—	2, 7		
TR5	0.069	0.031	1.33	1.5	—	—	6, 6, 4	7	6
	0.155	0.069	↓	↓	—	—	6, 6		
	0.309	0.137	↓	↓	—	—	3, 4		
TR6	0.069	0.023	1.57	1.75	—	—	5, 5	3, 7	4.5
	0.105	0.034	↓	↓	—	—	4, 6		
	0.211	0.069	↓	↓	—	—	4, 2		
TR7	0.1725	0.069	2.0	0.5	0.1	0.01	7, 4	5	9
	0.2	0.08		↓	↓	↓			
TR8	0.1725	0.069	1.0	↓	↓	↓	8, 8	7	9
TR9	0.1725	0.069	0.5	↓	↓	↓	7, 6	9	9
TR10	0.1725	0.069	0.75	↓	↓	↓	7, 5	8	
	0.02	0.008	↓	↓	↓	↓			9
	0.0035	0.0014	↓	↓	↓	↓			8
	0.015	0.006	↓	↓	↓	↓			10
TR10	0.137	0.003	0.75	0.5	2.0	0.01	7		
	0.206	0.004	↓	↓	↓	↓	7		
	0.859	0.017	↓	↓	↓	↓	7		
	1.718	0.034	↓	↓	↓	↓	10		
	0.137	0.018	↓	↓	3.0	0.1	10		
	0.275	0.037	↓	↓	↓	↓	4, 5		
	0.258	0.034	↓	↓	↓	↓	7		
TR11	0.272	0.017	0.125	4.0	—	—	8, 10	10	9
TR12	0.153	0.017	0.167	3.0	—	—	5, 9	9	5
TR13	0.276	0.069	0.25	2.0	—	—	9, 7, 9, 8	10	10
TR14	0.069	0.069	0.5	1.0	—	—	4, 4	7	6
	0.034	0.034	↓	↓	—	—	7		
	0.137	0.137	↓	↓	—	—	7		
TR15	0.1725	0.069	3.0	0.5	0.1	0.01	7, 7	7	8
	↓	0.004	↓	↓	2.0	↓			5
TR16	0.4658	0.069	1.0	1.5	0.3	0.1	4, 3, 4	3	3.5
TR17	0.431	0.069	0.6	2.5	—	—	9, 9	10	9.5
	0.214	0.034	↓	↓	—	—	4, 5, 6		3.5
	0.862	0.137	↓	↓	—	—	10		
	0.107	0.017	↓	↓	—	—	2, 2, 2, 4		5

Table A-1. List of Configurations and Pilot Ratings

Configuration	Blending Schedule	Stick Sensitivity	Hover System	Pilot Rating A	Pilot Rating B	Pilot Rating C	Comments
B143	10 kts; 10 sec	0.137 rad/cm	TR4	3-Blend 3-Overall	8-Rate 3-Att	2-Blend 6-Approach 4.5-Att	Well Damped, Blending Good Blending is Transparent
B343	10 kts; 5 sec	0.137 rad/cm	TR4	4	7-Rate 3-Att	4-Blend 5.5-Approach 5.5-Hover	Blending not Difficult Abrupt Change in Roll Command
B421	15 kts; 15 sec	0.069 rad/cm	N1LAT	3-Blend 7-Retransition		6.5 App/Land 3.5 Accel from Hover	Abrupt Change in Blending Doesn't Like Retransition Can't Sort Out Particulars
B231	15 kts; 10 sec	0.103 rad/cm	N1LAT	3		4	No Problem with Transition Blend Transparent
B522	20 kts; 0 sec	0.069 rad/cm	N2LAT	8		8	Too Abrupt of Change
B124	10 kts; 10 sec	0.069 rad/cm	TR5	6			Blending Not Acceptable
B516	20 kts; 0 sec	0.034 rad/cm	TR17	7			Disconcerning Jump in Blending Control in Go-Around Disliked
B312	10 kts; 5 sec	0.034 rad/cm	N2LAT	7			Lateral PIO

GP23-0519-519-40

Table A-2. VTESA: Approach Task Summary Sheet

Configuration	Blending Schedule	Stick Sensitivity	Hover System	Pilot Rating A	Pilot Rating B	Pilot Rating C	Comments
B226	15 kts; 10 sec	0.069 rad/cm	TR17	5			Blending is Good Retransition is Too Slow
B323	10 kts; 5 sec	0.069 rad/cm	TR4	6			Blending is Nice
B423	15 kts; 15 sec	0.069 rad/cm	TR4	7			Discontinuity in Blending
B125	10 kts; 10 sec	0.069 rad/cm	TR14	7			Blending is Indistinguishable
B534	20 kts; 0 sec	0.103 rad/cm	TR5	7			Objectionable Blending
B345	10 kts; 5 sec	0.137 rad/cm	TR14	9			Transition isn't Too Bad; Does Have Discontinuities
B122	10 kts; 10 sec	0.069 rad/cm	N2LAT	7			Blending Schedule Too Long
B121	10 kts; 10 sec	0.069 rad/cm	NILAT	4			Blending is Nice

GP23-0519-41

Table A-2 (Continued). VTESA: Approach Task Summary Sheet

Configuration	Blending Schedule	Stick Sensitivity	Hover System	Pilot Rating A	Pilot Rating B	Pilot Rating C	Comments
B223	15 kts; 10 sec	0.069 rad/cm	TR4	7			Initial Blending is Good Retransition Too Long
B524	20 kts; 0 sec	0.069 rad/cm	TR5	6			Blending is Disconcerning Final Blending is Good
B525	20 kts; 0 sec	0.069 rad/cm	TR14	6	7		Quick Transition; PIO on Blending
B321	10 kts; 5 sec	0.069 rad/cm	N1LAT		6		Didn't Notice Blending; Blending is Transparent
B116	10 kts; 10 sec	0.034 rad/cm	TR17	3, 7-Overall 5-Approach		2-Blend 9-Reblend	Smooth Transition; Long Time to Blend from Attitude to Rate
B316	10 kts; 15 sec	0.034 rad/cm	TR17	10			No Response During Blending
B526	20 kts; 0 sec	0.069 rad/cm	TR17	9		2-Blend 8-Reblend	Blending Causes Lateral and Longitudinal P.I.O.
B356	10 kts; 5 sec	0.052 rad/cm	TR17	10		4-Blend 8-Reblend	Blend is Unacceptable
B246	15 kts; 10 sec	0.137 rad/cm	TR17	10-Retransition		2-Blend	Blending is Transparent

GP23-0519-42

Table A-2 (Continued). VTESA: Approach Task Summary Sheet

Configuration	Blending Schedule	Stick Sensitivity	Hover System	Pilot Rating A	Pilot Rating B	Pilot Rating C	Comments
B431	15 kts; 15 sec	0.103 rad/cm	N1LAT	3		4.5-Approach 2-Blend 5-Hover	Blending Transparent; Blending is Confusing
B136	10 kts; 10 sec	0.103 rad/cm	TR17	10-Retransition			Blending is Docile; Retransition Nose Drops; is Driving Rating
B426	15 kts; 15 sec	0.069 rad/cm	TR17	4-Blend 5-Reblend			Retransition is Too Long

GP23-0519-43

Table A-2 (Concluded). VTESA: Approach Task Summary Sheet

APPENDIX B

PILOT COMMENTS

Pilot comments presented in the Appendix are shown essentially verbatim. Only minor editorial changes have been made.

The pilot rating and the off-nominal steady-state gain are listed with the pilot comments.

CONFIGURATION TR1
K_{ss} = .031 rad/cm

PILOT A: 7
We got an attitude system. It's a little sluggish. It takes me a long time to stabilize. Approaching stabilized hover position moving into the platform. Over the pad coming down. I just can't stabilize. Too sluggish in attitude. Never got to touchdown. I have landed with this one but it's more or less by chance. I can't satisfy all the requirements simultaneously except by luck. With the attitude system it takes quite a while to respond and ... it takes quite a while to stop the airplane and start it or what have you. You just can't really stabilize it. I don't know if there is wind over deck, it feels like there is. I can never really settle the thing down and stop it where I want to over the pad. So only by a fluke can I get a touchdown. So that means I can't get adequate performance no matter what I do with it. So I'll have to give it a 7. Adequate performance is not attainable. It is not just a matter --- there is no controllability question unless you want to talk about ramming the ship, it just doesn't respond fast enough. Cooper Harper 7.

PILOT A: 4
Okay, attitude system well damped, slightly sluggish. Feels solid as a rock. Just have to lead it a little bit. I think I would like to have the response up just a shade on that, but I think I can do the job. I'm not quite getting down in the precise spot. When I get in this close to the ship I don't have a horizon reference. So I don't know where neutral is, which makes it a shade confusing so, being a little bit off the spot on this one is a partial display problem. I wish the sensitivity was a bit higher then I could make things happen a shade faster. That means that I have to lead things by a fair amount to get the performance level I want. But on the other side of the coin it is as stable as a rock. Very predictable -- very controllable. So I wish the responses were up a bit, but I don't have too much difficulty with it. I can get the desired performance out of it as far as the dynamics are concerned by furnishing some lead. Cooper-Harper is a 4.

PILOT B: 3
This is an attitude system. At least laterally. I'm not sure about longitudinally. It's an attitude in lateral and I'm not so sure but, yes, it is longitudinally too. I really didn't have any real problems with that. I would give it about a three laterally and longitudinally. It seemed to be well damped and not a real problem to fly.

PILOT B: 7 — Attitude. It's a little sluggish. It's a little too sluggish I think again for the gusty situation. I'd give this about a 7 just because it's just too sluggish. It's damped nicely. You can fly it fairly precisely as long as you don't end up with a requirement to do a rapid change in attitude.

PILOT C: 6 — I'm going to preface this by saying I think I may still be a little bit on the learning curve. So you may want to come back and repeat some of these first ones. But I'm just going to go ahead and rate assuming that that's not the case. And we'll see how it is on the repeat. I give that one a 6. And the major deficiency is -- it's an attitude system and my major objection to it is that I can't get enough precision attitude control to control my position. And another thing that leads to that rating is that the throttle response is pretty good but it still requires some work to stabilize the sink rate. And so the heave damping is not real good and so I spend a lot of time on that side task. And so that right away would put it up, you know, into the 3 and 4 category and then with that loose attitude control it goes to a 6. So, as far as path control I would say that the path response is moderately sluggish and the attitude response I would call excessively sluggish, for that combination of attitude and path. And then going down your list, feel systems seems fine. And the, of course, the visual display I think is excellent although I had one problem -- when I'm over the deck down in close I do have a little problem when I pitch down, I get the initial impression that I'm moving backwards because of the display. And instead of forward which is what I should do when I pitch down so I get some control reversals right over the deck.

PILOT C: 5 — That one is definitely an attitude system and I'm sort of torn between a 4 and a 5 on it. I'm not sure if I flew it over and over and over again if I couldn't get used to the somewhat sluggish dynamics. I think I'll go with a 5 because I feel it is just too sluggish and it is pretty unforgiving of any errors or lack of line-up. And again because of the very -- kind of sluggish pitch response and problems in setting pitch attitude accurately. It's a 5.

PILOT A: 4 — Better sensitivity -- it's still, well, not too bad, actually. You can get into but back out of trouble and I don't really have a lot of tendancy to get into a sustained oscillation. What you got is a relatively high sensitivity -- relatively high gain and moderate acceleration. So the combination is tolerable. With a

faster reaction that level of gain would be too much. With this amount of rate build-up you can realize what you have initiated and stop it before you get into trouble. So it balances. I would like to see for, you know, totally desired performance, less sensitivity and faster rate build-up, you can certainly do a good job with the airplane. I've got to sort of stay on top of it. I'll give it a Cooper-Harper 4. That's attitude.

PILOT A: 3
K_{ss}=.137 rad/cm

Dynamics are pretty good. The acceleration/deceleration characteristic give me no problems. It's got good bandwidth. Very appropriate to the task. The static gain may be a shade on the high side but it don't give any problems. The attitude response is docile. A 3 -- that's good. It's an attitude system. Well behaved. The static gain is a shade on the high side. That's the only reason it is not a 2.

PILOT A: 6
K_{ss}=.172 rad/cm

It's something you can adapt to. It's an attitude system .. very, very high gain. Very, very quick dynamics. I think in close, those offset rates would be totally unacceptable. Instant P.I.O. and instant vertigo type stuff. I've got to furnish a reasonable amount of compensation on that one by keeping my own bandwidth down or I could get into trouble in a hurry. I can get performance, but I really got to stay on top of it. Cooper-Harper 6.

PILOT A: 3
K_{ss}=.137 rad/cm

I would change a little bit of the static gain on that to a little faster acceleration. It's an attitude system. It's pretty docile. It's pretty controllable rather. I wish it would accelerate slightly faster. I would trade some of the high gain for that. It's annoying rather than anything else. Cooper-Harper 3. It's certainly adequate.

PILOT A: 6
K_{ss}=.172 rad/cm

It's relatively brisk responding -- relatively slow on the wash-out. It's attitude, but it has a lot of the characteristics of a rate system. It's sort of hard to call. Okay, attitude type system -- the static gain is pretty darn high. The dynamic build-up is a shade on the high side. That's due to the gain. I think the time constant on this I would find acceptable at the reduced gain level. Well, I don't know. It's awfully puzzling. I have a problem with the sensitivity configuration and sometimes I think it's the gain and sometimes I think it's a time constant. I do know it's got too much gain. So the gain is too high. Maybe the only thing that is making it flyable is that the time constant is lower than desirable. I don't know. At any rate I'll have to say on that configuration, the static gain is too high and it means you have to...(end of tape).

CONFIGURATION TR2
K_{ss} = .0225 rad/cm

PILOT A: 4 Pretty nice system. It's attitude, slightly faster responding. Coming up stabilizing. Stabilize over the hover pad. Precision. Right square on the dime. Okay, that is approaching the desired category. Still would like a shade faster reaction. That might not be tolerable in a real aircraft so for this configuration which is attitude and a reasonable response out of it, Cooper-Harper 4. It would be a 3 except the overall difficulty of the task.

PILOT B: 4 This is another attitude system. It's nicely damped and everything. I'm not having any problem at all flying it with a reasonable amount of precision. I'd give that about a 4. For some reason I don't think it was damped quite as well as the others. It just wasn't quite as stable. I'm hardly using any movement of the stick at all.

PILOT C: 5 On that one I seemed not to work harder on. And -- so the attitude seemed a little looser. I guess I would give that one a 5. I had a couple of really bad times when I got off the nominal course, there -- it seemed to kind of wallow around -required a lot of pilot compensation to correct the tendancy of the thing to wallow. So you had to stay quite a bit ahead of it, and so I would give that one a 5 for that reason. And it's definitely an attitude system but it appears to be a fairly sluggish one. All these attitude systems that I've flown so far, by the way, have good damping, it is just a matter of they -- some of them are more sluggish than others. And I think the comments about path are all the same, you know, it's the same thing of -- it's fairly low -- it feels like the airplane has a fairly low heave damping. And so you just have to stay quite a bit ahead of it on the path response to throttle. And I noticed here you have effective wind and turbulence and I really don't see any effect of that -- although I think if you threw that in here it would probably make things considerably more difficult and they were already quite difficult -- fairly high authority, high gain task. And again one final comment and that is when I get over the deck I tend to get a little lost in my -- in the cues that I'm looking at between -- what's pitch attitude and what's translation. When looking out the window here. And just for the record, as far as the HUD goes, there's just no time to look at it. So I really - I'm paying literally zero attention to the HUD. Everytime I try to look at the -- except for the

dumbbells on the -- to tell me how high I am above the pad and I use those to judge whether I'm going to hit the edge of the ship or not as they come across the end. But other than that I'm not using the HUD.

PILOT A: 7

The attitude is sluggish. In terms of gain it seems a shade deficient in terms of gain, but it's woefully inadequate in terms of rate build-up. It feels as solid as a rock, obviously. Just sort of stays there. You know, if I've got to lean on it and disturb it from it's intended position. The only way to fly some of these is just what I just did sort of a roll on where you just get everything to converge. And that would be rather difficult to establish a full hover precisely and then let down before the wind, or something drops and you started drifting. So let's try that. Well, just about got into a stabilized hover. I can never null everything out at the same time. Okay, the problem with configuration is a combination of low sensitivity and low rate build-up. The sensitivity, in terms of degrees per inches, inadequate, or at least marginal. This fast acceleration, you may be able to tolerate it but the rate at which you get -- the combination of which you get it and the command available means that if you ever got the thing pointed at the ship with a closure rate there's no way in hell you can stop it. Definitely inadequate for ship board use. Cooper-Harper 7. No problem with control, just inadequate around the boat.

PILOT A: 3
K_{ss}=.30 rad/cm

I'll rule that one Cooper-Harper 3. The acceleration - the c-ispness of the response may be a little bit abrupt in a real airplane. And a fixed based simulator gives you very precise control over what you're doing for this task and a fixed based simulator it is definitely Level 1. You couldn't ask for much better -- more precise response. That may be a shade abrupt in flight.

PILOT A: 5
K_{ss}=.069 rad/cm

That's a shade disconcerting. It feels like a blend between an attitude and a rate sometimes. Really lean on it you get lots of attitude. And I think it is an attitude system with relatively slow dynamic build-up for a very very high gain. It is a little puzzling to find. Things happen nice and slow but if you need to stop or to get it going, you can. It developes tremendous attitude in a hurry by really leaning on the control. I didn't generally get into trouble with it, but it gives you the feeling using a normal control technique that you don't really have total control over it. That it's a deficient response, but you got enough available. It's sort of puzzling to fly. I don't like it. I have to go with a Cooper-Harper 5 again.

PILOT A: 8
K_{SS}=.137 rad/cm

That's just a bit too much. I'll call it an attitude system -- fast dynamics. Very fast dynamics and very very high gain. Would be a.. Controllability becomes a question on that thing. If you get rambunctious you're going to do something dumb like I did in that last one and you could go straight up or straight down. And it's just got too darn much gain. So, I'm stuck somewhere between a 7 and an 8. I'd say that it's probably unacceptable for use in close confines because of the high gain and that's primarily the controllability question. I'd give it an 8. Too sensitive.

PILOT A: 5
K_{SS}=.034 rad/cm

That's good. I think we can control it. I wish things happened a little bit faster. I can't really make it go into, you know -- cause me to lose control or to get into a P.I.O. or anything like that. I just wish that it was a little bit more responsive around the ship. Not much, just a little. All told not too shabby. I can certainly get an adequate performance. The question is am I really getting what I want in the desired performance? And since there is a question, I'll say not. If I -- I can certainly get the adequate performance. And it's a Cooper-Harper 5 and darn near a 4. Attitude system.

PILOT A: 3
K_{SS}=.137 rad/cm

I think this is one of your funny rate ones. I can put it [illegible] place and it tends to more or less stay there, very slowly wash out. In other words, you have to keep pointing it. Controllability is pretty precise, as long as I know where I want to put it I can put it there with no problem. Once more. That's a rate system that is about as good as I've seen. It would be a lot better with more precise attitude reference but as long as I keep it flying where I want to go, if I evaluate it on--if I know where I want to put the wings and the nose, it goes there with a minimum of effort. It's pretty darn nice. Cooper-Harper 3.

CONFIGURATION TR3
K_{ss} = .0173 rad/cm

PILOT A: 5
I guess I'm going to have to hedge on what I'm calling a attitude or a rate. That was a pure attitude. You got attitude response to a stick position that was a bit easy to control. The other one I guess the problem was the rate. You've got pure attitude, I got a touchdown and it's still a little sluggish. I got the touchdown. A little short of the center of the pad, but pretty close. Okay, it's a little more than I would like to see. I would like to see a little bit faster response. It is much more controllable. Better controllability. I guess I would like to see faster response. I can compensate for it as long as we don't have a pitch and heaving deck and things like that. So what have we got. We've got to compensate to get the performance we want. I can get the desired performance, I just can make it go fast enough. I'll give it a Cooper-Harper 5.

PILOT A: 4
It seems to be about the same so the attitude system is stable, very well damped. Okay, the sensitivity is slightly better. That's about as close to the pad as I'm going to get. Yes, now the technique there, of course, is that I got the thing more stabilized when I still had an attitude reference, before I set it down. Yes, I think the problem is basically, without an in close attitude reference, sometimes I can't quite hit the dime. Okay, that is an attitude system -- well damped. About deadbeat. I can use a shade more sensitivity, so it is a mildly deficiencies category. I can get the job done certainly. I guess my only gripe is that I wish the sensitivity was a shade better. Okay, Cooper-Harper 4. That's a borderline Level 1.

PILOT B: 3
That's another attitude system. I give that about a three also. I didn't feel the thing was very difficult to fly and it was stable, well damped.

PILOT B: 7
This is an attitude system. The response--it's damped nicely but the response is too slow. It's one of these system that you can fly but the response is just slow to really fly safely in an area where you might need to correct for a back angle, a gust change. I give that a 7.

PILOT C: 4
Right off it feels like this one has a little better attitude control. It is a little snappier than the others I've flown. At least that's my initial impression. The more I fly here the more I realize that the height control problem is a major major task. That was definitely much better. That one I'll give a 4 and I think most of that rating is due to the height control

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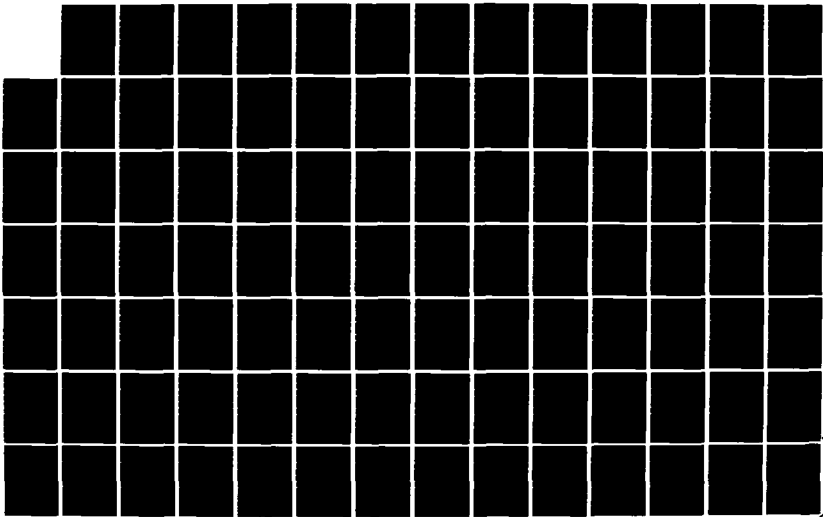

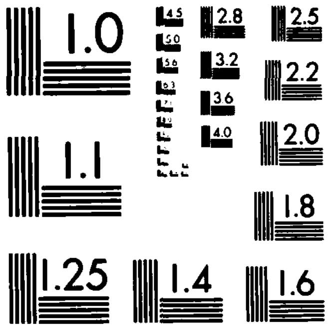
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problem and the fact that my initial condition - you know, I'm not in a stabilized approach very in close to the ship, primarily in height control. And so a lot of that 4 has to do with my glide path control with throttle. And -- but the attitude control seemed much much better that time and if I was to rate attitude only I believe it would be between a 2-1/2 and a 3, for only -- that part of the task - on controlling position. It's definitely an attitude system and the feel system was fine. No P.I.O. tendancies. And again - still a little problem with this initial apparent reversal on the display and I'm just getting used to using the -- out the side windows to help that problem. I think as I get more and more used to the display a lot of these problems will go away.

PILOT A: 4 K_{ss}=.034 rad/cm — All told pretty good, I guess I'd like to see it a shade fast in dynamics. Static gain is good. Controllability seems to be excellent. I could make it move, but if I really want to develop fast accelerations/decelerations, I have to overdrive it because I've got to compensate. Cooper-Harper 4.

PILOT A: 3 K_{ss}=.069 rad/cm — I don't think you can divorce the acceleration -- I don't think you can divorce time constant from gain. It feels like you've got some time delay in this one. Okay, the attitude system -- the gain may be a shade high, the dynamics is a shade low. At the point between the high gain and not too brisk dynamics, it means it is controllable. Actually, it is fairly pleasant to fly. Okay, on this one it is pretty decent. It's got a few quirks I don't like. I think I would trade some of the gain for -- I'd trade a lot of the gain for the faster acceleration. But again the combination is pretty good. If I need more, it's there. I just got to ask for it. So, there's a bit of compensation that has to be done. It's down near Level 1. I'll say Level 1. I'll give it a 3.

PILOT A: 3 K_{ss}=.034 rad/cm — And a very slow wash out toward the wings level. Another one of those blend type systems. The controllability doesn't seem too bad. This is pretty darn nice. I can get more than adequate control if I lean on it a little bit. Three! Pretty nice. It's definitely Level 1. You have to do very little to get it to do what you want. It could go a little bit more sensitivity -- could become a two, but you've got more that enough sensitivity there if you just leaned on it a little bit. It's got -- relatively easy to get the levels of performance you want out of the airplane. Pleasant!

PILOT A: 4 K_{ss}=.069 rad/cm	Not totally ideal, but pretty good. Fairly precise control. I think you could tolerate having slightly lower static gain, maybe slightly faster than dynamic build-up. The static gain definitely is a little on the high side. I would say it is an attitude system. I guess I would say to make it better trade some of the gain for some faster dynamics. Desired performance can be obtained. Cooper-Harper 4.

CONFIGURATION TR4
K_{ss} = .069 rad/cm

PILOT A: 5 — Attitude system, reasonably sluggish. That was my experience with the rate system a few minutes ago, sort of sneaking up on everything here. Looks like I've got realtively good controllability. Pretty damn high. Getting some choppiness in the display, now the box is jumping around the display slightly. Just a couple mils, now it is stabilized. Got my 15 feet. Over the fantail. Sliding on the gun. Nice and stable. Stable as a rock. Got her down right precisely on the dot. Wish this thing reacted faster. Certainly adequate for the task. Not quite the desired performance I would like to get. If I get going a little too fast in close confines, I have trouble stopping it. Cooper-Harper 5.

PILOT A: 6 — This looks like a translational rate command system. I get very little attitude motion, but I seem to have adequate control so far. Let's see if I can stop it. It's a rate system with very low sensitivity. Got to stay ahead of it. If you stay ahead of it, the control is deadbeat. Controllability is not a problem. Adequate performance, the problem is the sensitivity is so darn low that you really got to get out ahead of the airplane. That means you have to furnish extensive compensation, but assuming you stay ahead of it, I think you can get the job done. I think you can get into trouble with it if you try to make things happen too fast. Very objectionable, but borderline tolerable. Cooper-Harper 6. That's an attitude.

PILOT A: 5 — K_{ss}=.138 rad/cm — That's a pretty decent system. I've got full left stick in. I'm still getting messed up with that lag up in attitude in here. Even this doesn't help too much. I believe attitude sensitivity seems good. Response could be a shade brisker but not too horrible. I don't have too many problems with it. Attitude cue deficiency in close, just totally destroys you. I want to give this thing a better rating than I'm going to because it's a pretty docile airplane but I just don't have the cues I need to do a precision hover task. I can't get the level of performance that I think I should. Cooper-Harper 5.

PILOT A: 7 — K_{ss}=.034 rad/cm — If you increase the gain by two or three hundred we may have something. Stable as a rock obviously. You've got to think inches per second here. That thing is very, very slow to move, accelerate, decelerate, stop, or anything else. I'm in a vertical P.I.O. among other things. I'm over the pad and out of time. I think you've got another Level 3. Controlled crash. I'm not

real enthusiastic about that. It would be horrible easy to get into trouble. Controllability is no problem. It's it just may do anything. You can't loose control. You never have it. Adequate performance not attainable certainly. Give it an upper 7. Attitude. I don't know. I didn't have enough response there to tell the difference.

PILOT B: 7 — This is an attitude system. It's damped almost too much. It's too slow to respond. I'd give that about a 7 because of the slowness of response.

PILOT B: 6 — This is an attitude. Response is a little better than last time but it's still too slow. I'd give that about a 6. Response is still too slow. That was attitude.

PILOT A: 4, K_{ss}=.137 rad/cm — Rate. This one I can avoid crashing in. Puzzling! Sometimes it flies like a rate, somtimes it flies like an attitude. In close it feels like an attitude or a rate system. Far away it feels like an attitude. I don't know. I'd have to say it's got a lot of the unpleasant attributes of an attitude...of a rate system in close. And I never really know where neutral is. I'm not really sure what causes that. In close I'd have to judge it as a rate system...you know because of the precision. In other words, because I had a lot of trouble finding out where neutral is. Response to this is down a little bit. However, I can handle it. I give it a Cooper-Harper 4.

PILOT A: 5, K_{ss}=.275 rad/cm — It feels like one of them there sluggish rate systems. I'm going to have to make a roll on landing. This is an attitude system that flies like a rate system. It's got a lot of static gain but a slow dynamic build-up. I'd trade a lot of that gain for faster dynamics I believe. All told, I really don't like it. If I can get adequate performance out of it -- I've got to sort of stay on top of it. Cooper-Harper 5.

PILOT A: 6, K_{ss}=.137 rad/cm — This one has got low deficient response for shipboard use. Too easy to get into trouble with that one. Static gain is relatively good. The dynamic build-up is awfully inadequate. I can do the job but I sure got to stay ahead of the airplane. Okay, I can get adequate performance--I'd certainly like to have a heck of a lot more gain than that around the ship. Cooper-Harper 6. Attitude. I think the gain is okay, but the rate build-up -- the dynamic response is inadequate.

PILOT A: 6, K_{ss}=.275 rad/cm — Sometimes I think he's good, sometimes I think he's bad. That is going to have to resond faster. Cooper-Harper 6. I can get the job done but I certainly wish it responded faster in attitude. I'm going to say it was one of those funny rate systems. It has a tendency to stay where I put it until I take it out.

CONFIGURATION TR5
K_{ss} = .031 rad/cm

PILOT A: 6 — Back on attitude type system, I think, I can't really tell. It is just too darn sluggish and this thing is dangerous around the boat. I never did get a touchdown. Stabilizing about 15 feet, coming up on the pad. We've got an attitude system. Let me think about what we've got here. We've got an attitude system, sluggish. I made a pretty good approach and landing by just sort of sneaking up on it, taking things nice and slow. Stabilized and dropped it. However, if you miss, you have trouble when you start getting close to the super structure of the ship you can't make this thing respond very fast. That can be dangerous in close confines. You really got to sneak up on the pad. So we are back to where I can't get desired performance because it doesn't react fast enough and adequate performance requires quite a bit of compensation. I can get it down. Let's give it a 6. Attitude.

PILOT A: 6 — We've got ourselves an attitude system, sensitivity is down fairly low. With the sensitivity and the rate, so it would be -- the sensitivity could stand to be a shade higher in terms of absolute response per inch. And also the rate at which I get it to be higher. Okay, moving into stabilized position. I can get it down fairly well. What I'm interested in is kind of -- I really stabilize it in a precise hover. My original comments hold. Sensitivity is low and the rate of build-up is low. Now, what I'm interested in seeing this time is -- you know, before if I just, you know, just watching all the rates come and go and I got it down with tolerable accuracy. What I'm interested in is can I actually get into a hover position and hold? Just barely! Okay, so sensitivity is low -- the rate of build-up is low. As long as I stay ahead of the airplane and sneak up on a task I can get it down. I'd sure like to have a lot more response so I'm going to call it very objectionable -- horrible deficiencies. You really got to stay on top of it. Cooper-Harper 6.

PILOT B: 7 — This is another attitude system. This is almost not enough rate. It's almost damped so much that if I --- it's probably okay as long as I'm not in turbulence. But if I got into any turbulance with this particular system I'd have some real problems. I think it's damped too much. It's just damped too much. When you put a deflection there, you ask for a deflection, you really have to go full stick before you hardly get any movement at all. I can fly it as long as I don't end up getting kicked off somewhere due to a gust of wind or something. As soon as I got into some wind I'd be in deep trouble

because I'd probably end up getting kicked one way or the other and then not being able to correct for it quickly enough. I'd give that about a 7. It's controllable but it's unacceptable.

PILOT C: 6
That was again an attitude system, but a sluggish one. It was hard to distinguish between the -- I'm finding that they don't look all that different to me and although that seemed even maybe more sluggish than the others -- so, I'll give it a 5-1/2. Just because again, it seemed very, very sluggish and I noticed it was okay on the approach but when I got over the deck and needed some precision to hover -- I think about a 6. Let's lower that to a 6. When I needed that -- some precision to hover over the deck, it just wasn't there. The response was too - the stick in close was just too slow. So that would be a 6 because of the sluggish attitude response. And I'm finally starting to come up with a way to compensate for what appears to be low heave damping in the path control and that is kind of pulsing the throttle - before I develop a sink rate I give it a pulse to full throttle and then back to -- back to my nominal power setting and that seems to stop the sink rate and so you'll see more pulsing in the throttle and that seemed to work a little better.

PILOT A: 4
Another attitude system. So far it feels relatively precise. That's a little loose in the axis. I think this one would be imminently suitable if I had a slightly better attitude reference. Okay, I'm going to stabilize the hover over the gun deck. Move it up forward to the pad. Drop it in. Go for a stabilized hover. Oh, I don't know, I guess I got -- would like to accelerate just a shade faster. As you can see I can sort of repetitively get it down with several different techniques. You can get adequate performance. The fact is I think if you can stay a little bit ahead of it you can get desired performance. I'll give it a Cooper-Harper 4. I would like to see the rate build-ups a shade higher.

PILOT A: 3 K_{ss}=.137 rad/cm
I think you finally learned how to build a rate system that flies...or is it? Sometimes It feels like a rate, sometimes it feels like an attitude. It has alot of the attributes of a rate system. I put it somewhere it tends to stay there. If I hold it somewhere, it doesn't continue to accelerate...I'm gonna have to say it's some variation of a rate system. Dynamics are not too bad. I guess I'd like just a shade faster acceleration, but all told, it's a pretty docile animal. Cooper-Harper 3.

PILOT A: 6 K_{ss}=.069 rad/cm

Oh, I'm sort of stuck on that one. Sometimes I get a lot more out of it than I really think is there. I would have to say that I would dearly love a faster response and about that point I've got to over drive it to get an acceptable level of performance. But I think I can. Cooper-Harper 6. It's a ... the build-up is down. That means in order to get it to move I really lean on the stick. In other words, in order to get a specific rate that I want and get it in a hurry, I've got to ask for four times as much and then back away from it. You can get sluggish dynamics with a high gain and then maybe it all works out. It's a bandwidth type thing. And that one I think is dynamically too slow.

PILOT A: 4 K_{ss}=.137 rad/cm

This one doens't have any strong preforence about where it wants to go. So, I guess I'll say it might be one of those rates. But it's a little better than the previous system. Slowly washes out. Well, that's a little puzzling. It's a high gain attitude system in some respects and then it's a rate system in the other. It's very responsive to a stick input, and very slow to wash out the wings level. The static gain is relatively high. If you really do something dumb you could get into trouble with it but you never really notice that you've got that level of sensitivity with the normal piloting technique. It's really not too shabby. I think the precision control on that thing is excellent. I worry about having that level of gain in it though. I can generally make it do what I want. Cooper-Harper 4. It's just a bit on the sensitivity side as far as the gain goes.

PILOT A: 6 K_{ss}=.069 rad/cm

This is an attitude system. Standard gain is okay. The dynamics build-up could be faster. The dynamic gain should be faster. I'll say I can certainly get an adequate performance out of that one. My objection is I wish it had a faster rate build up. Cooper-Harper 6.

CONFIGURATION TR6
K_{ss} = .0225 rad/cm

PILOT A: 5
It's another attitude system. It's still pretty sluggish. Another attitude system, seems a shade on the sluggish side. I can get the job done, got to think ahead a little bit and don't get my expectations too high about the rates I can control, I just got to sort of sneak up on the pad and stop and drop it. Adequate performance is attainable. Desired performance, no, I'd much rather have it go -- react a shade faster. So let's go with a Cooper-Harper 5.

PILOT A: 5
I think if you had gusts or something like that in there that might be a little worse. You've got to be a little tender with this -- you can get a closure rate going, it's hard to stop. Okay, the problem is that the responses are not enough. I can't get the level of performance. I can't make it go fast enough. Adequate performance, certainly. So it's somewhere between a 5 or a 6. I'll go with a 5. With turbulence or something like that it probably would have been a 6. But you've got a very steady state situation here and it is just a problem of staying far enough ahead of the airplane. So, if you add, you know, on one more task added to the task, it would have been a different story. I would stay with the 5.

PILOT B: 3
There again, I didn't really see that much difference between that one and the previous one. Another 3. It was attitude. Nice and stable.

PILOT B: 7
Okay, this is an attitude system. Again it's sluggish. You can fly it but it's too sluggish. I'd give it a 7. It's damped nicely, everything else. But it's just too sluggish and it was an attitude system.

PILOT C: 4.5
Okay, I'll have to say that one suprised me because when I flew it around I felt like the attitude was a lot looser but when I did the task it didn't seem as bad as I expected it to be. So, the same comment is good for the thrust -- of course it is the same through the whole experiment, so I won't continue to repeat that. The attitude control was definitely adequate. I would say that one would be a 4-1/2. And it didn't -- seem -- I hate to compare one against the other but it seemed a little looser than the previous one but not loose enough to fake my ability to do the task. So it would be a 4-1/2 and the primary problem I really had with that was mostly path control -- attitude response seemed quite adequate. And it was definitely not a -- not a rate system. It was an attitude system.

PILOT A:
4
K_{ss}=.034
rad/cm

The attitude system is a bit on the sluggish side. Dynamically it's okay. The static gain seems to be down. The dynamics are sluggish. Can do a precise job with it, I don't seem to be having any real effect of turbulence or anything like that. Okay we've got an attitude system. The response is down. It is a shade on the sluggish side. It is a combination I think of a little slow dynamically and a little low on static gain. You have to drive it to get the level of performance you want to get out of it. But you can achieve it. I would definitely like to have a slightly quicker response for key close confines, but by driving it I seem to be able to avoid getting into trouble. So what that's telling me is that I can get the desired level of performance but I've got to compensate for the sluggishness. I've got to lead it a little bit, so it is Cooper-Harper 4. I've got to compensate. I've got to overdrive it in order to get the performance I want.

PILOT A:
4
K_{ss}=.069
rad/cm

This is a reasonable compromise. That's again a sort of puzzling level. It looks like a blended system that you could put it somewhere and it stays there. You know, it doesn't .. if I put it someplace and neutralize the stick it doesn't immediately go back to level by itself. I have to put it there. It does not respond like a rate system. It responds like an attitude system and the initial response buildups and things like that so ...I think ... I guess I'll have to say it because it sort of stays where I put it or tends to and it's a very reasonable rate system. The dynamic buildups on that is good. Static gain is low, but the dynamic buildup sort of offsets that. But...if you don't tend to over control it - you have to work a little harder than if you absolutely desire to get response you want, but certainly there... Cooper-Harper is 4. I really think it's attitude, but it sure flies like a rate. If a put it some place it stays there.

PILOT A:
6
K_{ss}=.034
rad/cm

Okay, it's an attitude system. It's a bit on the sluggish side for shipboard use. You really got to lean on it. You could get a closure rate going and it would be hard to stop. However, you can get the job done if you stay ahead of it. Cooper-Harper is 6 with a hedge that I would certainly like to have better response on that around the ship.

PILOT A:
2
K_{ss}=.069
rad/cm

Fairly responsive dynamics. Slow to wash out. I don't have too many objections to this one at all. I feel like I've got very precise control over the vehicle. I've got no objection to it, I'll call it Cooper-Harper 2. Attitude.

CONFIGURATION TR7
K_{ss} = .069 rad/cm

PILOT A: 7 — Don't quite know what we've got here. That's a rate. I think it's a rate. Boo. Hiss. I think we got a rate, but I'm not horribly positive. I just can't stabilize it. I did manage to get it down by just sort of getting everything aimed right and just sort of crossing my fingers. I'm over the fantail approaching the back of the ship. Sensitivity is not too shabby. I can't quite get the acceleration and deceleration I would like. I got adequate control, I think. A little short of the center of the pad. Got mixed emotions about that one. If it is a rate system it's on the borderline of being able to do the task. I don't have the control I need to get into a stablized hover. What I just have to do is get everything sort of lined up at once and hope when I chop the throttle, I'm going to land. It responds fast enough that I'm not having severe problems with running into things. I just can't get it stablized. Combination of a bunch of things. So it is not adequate for the task. I wouldn't like to see this thing around a ship at all. Controllability is certainly not a question. Back to Cooper-Harper 7.

PILOT A: 4 — Sort of hard to tell what I've got. I think it is attitude. Sensitivity is fair. Acceleration is reasonable. Could be just a shade higher. Controllability is quite precise, or seems to be. I sort of like that one. Cooper-Harper 4. I'll call it an attitude.

PILOT B: 5 — This is attitude. Response is better. But it still, as far as I'm concerned, still a little sluggish. But it's better than the previous couple. I'd give that a 5.

PILOT C: 9 — K_{ss}=.08 rad/cm — Okay. That one's a ... that's a 9 and the reason it's a 9 is the attitude control is extremely sluggish and I find that precision attitude control for me is just impossible and since I can't control attitude very closely. I also can't control position and it results in a lot of wandering around and to my back up for that rating is that I'm interpreting control as inability to control position of the airplane and not the inability to control...to keep it right side up or anything. But there's no way I can do this task with this set of dynamics. So, it's a 9, and it's an attitude system. A very sluggish attitude system.

CONFIGURATION TR8
K_{ss} = .069 rad/cm

PILOT A: 8 — We've got ourselves a rate command system this time. I can already tell I don't like it. I can tell that because I'm up here at 200 feet wondering where the world went. I'm stabilizing again, about 20 feet altitude. Getting it down to 15, coming up over platform. Lordy don't like this t all. Find myself starting to use the rudders. 25 eet. Hopeless. Got myself into a relatively stable itude, about 15 feet and coming over the fantail of t ship, a little low. Oh, Lord! This can get really we in a hurry. I got it down but that was a fluke. Gc rate command. the rates are fairly slow. The sitivity is okay. Stabilized 15 feet over the fantail. Trying to stop somewhere in the vacinity of the pad. 15 feet. Pert near impossible! Okay, with a rate system like that, it's easy to get yourself in a situation where you are going beyond the small perturbation angles in order to try and stop the rates which inadvertently get developed. When you do it doesn't, it is not airplane like. You don't get the translation rates. Appropriate - wait a minute. I've got to think about that. Because with the translation rates I've seen it is just not approriate to the angles I'm generating, I don't believe. At any rate, we've got a pretty poor configuration.

I can't get anywhere close to the platform with those type dynamics. Really got to keep in mind what you are doing. If you are not concentrating fairly intensely, it gets away from you. So that puts it down to considerable pilot compensation is required for control so as far as I'm concerned it's an 8, around the ship. I don't know how much of that's influenced by perturbation dynamics, this thing will just keep tumbling if you put the stick forward and get a rate and it just a constant rate, I don't know how realistic that is in a hover. So we are in the 8, 9, 10 ballpark, I'll go ahead and give it an 8.

PILOT A: 8 — Well, okay. Let me back up on account of -- I guess the sensitivity is acceptable. I can get all kinds of response out of the system. It just takes an awful long time to get it. Oh! okay. It's just too darn slow. Sluggish -- I do believe it's attitude. Very sluggish. Lot's of sensitivity. You've got more than adequate steady state response. It just takes way too long to get there. I'm not sure if there's even any time delay or lag in the response, it is just horribly slow to accelerate. That means that you can get in trouble in

the configuration because if you get into a large attitude, you can't get out of it. Basically, you've got to put in almost intollerable amount of lead into this turkey. Very very easy to get in trouble. Controllability is definitely in question. You get into one of these attitudes like this one ... no, I don't want to take this to the ship. Okay, we're down on a Level 3 range, huh? Well, no I can't say I can get adequate performance. Controllability is rearing its ugly head on this one. You've got to stay on top of it or you're going to loose it. Cooper-Harper 8.

<u>PILOT B</u>: 7 Okay. This is better response. Whoa! And it is a rate system as near as I can tell. but its not damped well enough for my desires. It's a real handful to fly this thing with real precision. It's just not damped well enough. You can fly it but it's difficult. I don't like it as well as the attitude systems I've seen before and I give it about a 7 again. It's just difficult to fly precisely, it's not damped enough.

<u>PILOT C</u>: 9 Oops. This one wants to pitch down all the time. This is -- something -- well, I guess I flew it to the ocean in playing with it I forgot to look at altitude. It seems like this -- I can't trim this one up. It wants to keep itching down. The stick is -- this is -- it comes out very much like a -- I'm going to call it -- it is a rate system but I think the stick sensitivity seems awful high for it. I'm going to classify that as a rate system although it did have some attitude stability. The rate-like responses definitely dominated the attitude response. So, it's a rate system and I felt like my perception was -- the stick sensitivity was too high, but I just, you know, the perception I got. And I -- with the time allotted I wasn't able to do the task to get it on the ship. It was barely controllable for me in this task -- with this display. I think when you get these kind of systems even though this is a really excellent simulator display, I think the fact that you don't have the real world out there becomes more apparent. And so the need for attitudes cues is much higher here and I couldn't seem to ever settle on the right trim attitude and didn't have the precision to set my attitude like I wanted. And so it seemed like a very sluggish rate system. Undesirable rate system. So, if I can interpret control, as meaning flight path control, I'm going to give this one a 9, and that doesn't mean I had problems, you know, just staying right side up to meet my - the thing here says intense pilot compensation required to retain control -- and by that I mean control of position with respect to the ship.

CONFIGURATION TR9
K_{ss} = .069 rad/cm

PILOT A: 7 Got a rate system fairly sluggish. I thought it was. It is not too bad. Sort of rattling stick around neutral. I'm over the pad but I'm too high. Just sort of oscillating back and forth. Can't really stabilize it where I want to. If I get this thing down it will be a pure fluke. I'll get this thing down yet. rate system. Sensitivity is okay. It is just almost impossible to get into a stabilized hover. I don't know why. Okay, we've got 30 knot wind over deck with some turbulence so under those conditions, the rate system, now this is a normally docile rate system, probably representative to only appropriate damping terms and what have you in there of the Harrier. I can't stabilize it in hover ... it's a real bear. So what have we got. Adequate performance is certainly not attinable and I don't have the serious control problems I had with some of the other configurations where intense pilot compensation required to avoid hitting anything. You've got to watch what you are doing when you are in close confines but the response of the vehicle is adequate to get you out of trouble. So, we are back to the 7. It's unacceptable. You can't do the job. No question about that. Inadequate for the task, but controllability is not really a question. I don't know how you define that. If I can't hover it I'm having problems with control. I have the control response it is just the sensitivity I need to get out from close confines. I'm not having any real serious problems so I'll stick with a 7.

PILOT A: 6 You have a rate system. With practice this may be close to acceptable. I guess with practice, you could still have some problems. As a rate system, it is better than the underdamped ones. Let's try again. This is probably pretty close to the darn Harrier. Again, I get into that problem when I get in that close to the ship and lose that attitude reference I really have problems with these systems because I don't know where neutral is. I would like to see that one again. I want to make sure I am not biasing it because I can't see an attitude reference. There is definitely a problem of insufficient attitude reference to adequately control this particular airplane. So it is an attitude problem rather than something with a dynamics. For a rate system, these dynamics are pretty good. They are pretty appropriate. So of the rate systems, this is one of the better ones. The problem occurs with the rate system. Well let's go back in contrast with an attitude system. In an attitude system, assuming you've got the thing

trimmed, if you neutralize the stick, you go to something th-- -- some kind of trimmed up position. With a rate system when you let go of the stick, you must stay where you are. If the nose is up or down, you continue to translate. It is very hard when you get in close to the ship and you are looking into that hangar. Peripherally out the side you got a lot of black out there too. It is very hard to find out where you should put the nose in order to stop the rate. So I think it is a display problem more than anything else. I'm not real enthusiastic about these systems around the ship in general, but of the rate systems, this one comes close to having acceptable performance. So, Cooper-Harper 6. You can get adequate performance out of it, but you really have to stay on top of it.

PILOT B: 9 — Ah, this is not damped too well. It's a rate system. I just got into a big P.I.O. there. Tried to figure out whether it was a rate or an attitude system. Not damped enough. I don't think I can land it. That scared me. I'd give that a 9.

PILOT C: 9 — Okay, that's definitely -- I'm going to call that a rate system. It has some attitude stability but it is marginal and it is not even for all practical purposes there. The attitude stability is not there. And it is a very sluggish rate system -- a very poor rate system. I would call that a 9 again. And it seemed like this rate system and the other rate systems I've looked at, it is very difficult for me to distinguish between them. They all look like very sluggish rate systems and the difference is almost inperceptible. They all seem almost like the same system and that I would classify as extremely sluggish rate systems so that would be K/S out to some low frequency and then roll off. I feel mostly -- well, I guess sluggish is the main word that I can use to describe them. And there is not tendancy to P.I.O. It is just that I cannot make precision attitude changes and on the first run I gave myself the task of trying to change attitude on the HUD from one point to another using the HUD reference bars on the horizon. And I found that I just couldn't go and make an attitude change abruptly and quickly without overshooting and it just comes down to very poor precision of attitude control. And in trying to do this task that relates to an inability to control position because I can't control my inner attitude loop at all.

CONFIGURATION TR10
K_{ss} = .069 rad/cm

PILOT A: 7 — I just lost my engine noise again. Looks like you've got one of them basic rate systems dancing on the heads of a pin. You feel like you almost got a handle on it and then it does bananas. Okay, I'm over the gun deck, going forward. Well, I got it down, no where near where I really wanted to. It's not quite instable. You really got to stay on top of it or you get into trouble and the only way to get out of trouble is climb out of there. And part of this might be, you know, you're just really sort of devoid of good attitude cues. There's a real problem relating the attitude you're in to, you know, really accelerating and decelerating, you are in level, or what have you. When you got outside wall out there you can tell where everything is pretty much, but then when you get in by the ship -- except peripherally and even that's - in real close you will lose the peripheral cues. You just don't know where the level is. So, once you get in close over the hover pad there's a little bit of a problem figuring out the attitude you have to get to to stop rates from building. so that may be driving the task a little bit. You've really got to stay on top of this or you get into trouble. I'm somewhere stuck between a 6 and a 7 on this. It is a real bear. The reason that it was - you know, I got the airplane down and I think with practice I could get it down a little closer to the center of the pad which would say that, you know, extensive pilot compensation I could get the job done. On the other hand, it is not so much I'm in danger of losing control is that it would be very easy to let the airplane get away from me. and the controllability could become a question. So, I'll go ahead and stick with a 7. It is borderline Level 3.

PILOT A: 5 — I think you've got one of those squirrely old rate systems on me again. I'm so up so high, I lost the ship, so I don't know where the hell I am. I'm not sure I could even crash this one. Seems to be a rate system. If I drop the control strategy appropriate to the rate system, and rattle the old stick around and try to avoid getting into the large perturbation area, I run into that same problem. I just sort of lose the attitude reference. Given that we've got a rate system, I think sensitivity is reasonable. Acceleration could be a shade brisker. Again, one of the problems is I don't have the definite attitude reference I need. I'll give a Cooper-Harper 4 or 5. I'm trying not to let the lack of attitude display bias me too much. It's got to be in the moderately objectionable deficiencies. You can get adequate performance but you've got to stay on top of it. It's a 5. It's one of the better rate systems.

PILOT B: 8

Okay. this is rate system. I'll back up here a little bit. Yea. It's a rate system. Response is a little slow, a little sluggish for me. I guess my feeling about this is it's not damped well enough. But I'm not getting enough response either. So I've got two things going against me. It's not damped well enough and then when I ask for an input it's just not damped well enough. That didn't make any sense. When I need an input I move the stick and it rolls too slowly and yet I end up in more of a P.I.O. with this particular configuration too. I don't think it's damped well enough and I guess I'd give that about an 8.

PILOT C: 9
K_{ss}=.008 rad/cm

That's a 9 and the reason it's a 9 is the control sensitivity is just too low and it's extremely sluggish because it's ... and the attitude is sluggish, but the control sensitivity is so low that it's almost unflyable and ... you just don't have much control over the attitude of the airplane. Full stick results in an extremely low rates so it's a 9 on that basis.

PILOT C: 8
K_{ss}=.0014 rad/cm

Okay good. It doesn't feel like you..I mean it's stick sensitivity higher than it was last time and it certainly ... it feels like it could even be higher than what it is now if that's the one we're flying. Let me go ahead and make an approach with it now. Okay and I'm okay that one is a ... I consider the attitude control on that one inadequate. It's just too sluggish. I just can't stabilize attitude where I want it and as a result the ... the position is continually drifting around. I never could make a good landing on the deck and so it's a ... I'd have to say that I really didn't have control over flight path so it be an 8. And it was an attitude system -- sluggish attitude.

PILOT C: 10
K_{ss}=.006 rad/cm

That's a 10. And I don't think you could get it on the ship. Primarily the attitude response is extremely sluggish and just for approach it is just an acceptable thing. You can fly around with it and you can probably put it into a large area and I would say on the approach you would probably call it a 5 or 5-1/2. But for hover over the deck it is a 10, just because the attitude is too sluggish for that task. Yes, very very sluggish attitude system.

PILOT A: 4
K_{ss}=.005 rad/cm
λ =2.0 rad/sec

I guess I've got to qualify the comment that I think the gain -- the gain by itself is not sufficient. You also got to consider the rate of build-up. So, on this configuration you could have -- we could increase the gain as we just have and the controllability is much better, or conversely you could have kept the same gain

and increase the rate of build-up, and you've got about the same results. The system is fairly good. You got to stay a little bit ahead of it and compensate, but I think you can get fairly adequate performance with it. I would like to see a little crisper acceleration. So I'll go with a Cooper-Harper 4. Almost snuck into Level 1. That's an attitude system. If it had accelerated slightly faster, it would have been Level 1.

PILOT A: 10
K_{ss}=.002 rad/cm
λ =5.0 rad/sec

I've seen blimps that had better control. I can't even get closure rate going. I've got full forward stick, guys. I'm going backwards. Ten! Attitude and the gain is about 1/10 of what it could tolerate being. You just don't have any control over it at all. I had full forward stick with a one knot closure rate. Ten.

PILOT A: 7
K_{ss}=.0027 rad/cm
λ =2.0 rad/sec

Woefully inadequate bandwidth. It's the first one I've gone two block on. It just don't have any response at all and the short term static gain is a little low. The dynamics just aren't there. You can sit there and wave a stick around from stop to stop and not see any current response. You could really get into trouble with that ... get a closure rate and just not be able to stop it. Woefully inadequate dynamics. I give it a 7. It's just not safe for on a ship. Attitude.

PILOT A: 10
K_{ss}=.018 rad/cm
λ =3.0 rad/sec

On the attitude system the gain is next to non-existant. I have full forward stick and I'm making no headway. I don't have enough control to back away from it and I start moving forward again. It's just not enough forward stick available. And so if I ever hiccup and get going backwards, the ship would walk away from me I could never catch it. I'd land in the water. They would have to come and get me. You don't really -- I mean it's the control -- it's not a question of losing of control, it's a question of never having control. It's unacceptable. It's a 10.

PILOT A: 10
K_{ss}=.034 rad/cm
λ =2.0 rad/sec

How about 100! He's going to lose control over that. That's way, way too much sensitivity even when you're trying to make small inputs, the flicker, the jumping of the scene gets to you and if you just sort of blink you know you just lost the ship entirely. Totally unacceptable. Ten! I'd say it's attitude, but I could never really get a static stick position then because it is such a high gain I could never really tell what it was doing. I think it was an attitude with an exceptionally high gain high dynamics.

PILOT A: 4 K_{ss}=.037 rad/cm λ=3.0 rad/sec	I think it feels stable as a rock. It sort of totally ignores any external disturbances. You can do a very precise job of it as long as you don't get too excited. I wish it responded faster. I hate to use more gain and more dynamic response. Personally I think I would like a higher gain and faster dynamics - all of just high gain by itself might do it. Cooper-Harper 4. I could get desired performance. I get this feeling that I could get into trouble if I ever got a closure rate going. So I wish it responded faster. Attitude.
PILOT A: 7 K_{ss}=.017 rad/cm λ=2.0 rad/sec	Okay, I wanted this thing to roll ... a bit on the sensitive side. It's too sensitive around the ship but it's got some pleasant characteristics. It's a little too sensitive for close confine manuevering. You could get into a P.I.O. relatively easy. It's just too sensitive around shipboard use. There's too much response coming out too fast. The controllability is not a major -- there's just too much there. Land base I don't think it would be too much of a problem. Shipboard use is unacceptable - there's too much sensitivity in close confines. Cooper-Harper 7. Somewhere -- yes, Cooper-Harper 7. I'd call it an attitude.
PILOT A: 7 K_{ss}=.034 rad/cm λ=3.0 rad/sec	Dynamics are very slow on that, that I think you could really get into trouble. Static gain is pretty high but the dynamics are slow and you have the opportunity for a trade-off. Sort of stuck. Really like a lot more response than that around the ship. However, you can get the job done given the confines of the test. What I'm afraid of is that if you ever got in a real situation with a real wind over the deck and drop down like you do in close behind that hanging deck and the wind quit, you'd fly right through it. So given the confines of the task I can get the job done. I rteally don't think those dynamics are suitable for shipboard use. I'll just have to say given other things that could happen, you definitely want it to respond faster. I'm going to give it a Cooper-Harper 7. Attitude.
PILOT A: 7 K_{ss}=.004 rad/cm λ=2.0 rad/sec	Attitude system. Pretty sluggish. Could get in trouble with this one. Static gain -- I never really got a chance to look at static gain, per se, with large amplitude input. Gain could be a bit higher I think. The dynamics are woefully inadequate. If you ever get that nose down or up or whatever you just can't get it out with any reasonable amount of stick. Cooper-Harper 7.

<u>PILOT A</u>: 5 K_{ss}=.037 rad/cm λ=3.0 rad/sec	It's sluggish old attitude system. Doesn't have enough gain or enough dynamics. The problem is you'd get one of those closure rates going and you'd have yourself some problems. Actually it has better control than I thought it had. It needs more gain and acceleration, or maybe a combination of the two. Sensitivity could be up a bit, to give it more precise control for shipboard use. Certainly can get the job done with it though. Got to stay ahead of it. If you ever let the airplane get going I don't think you could stop it. Cooper-Harper 5.

CONFIGURATION TR11
K_{ss} - .017 rad/cm

PILOT A: 8 — Just above zero damping on this configuration. As long as we don't hit the control stick it's okay. Configuration is an attitude system. It's got about a zero damping, well, maybe not quite, but ... it's definitely damping deficient. Less than a tenth, I'd say. quite easy to get into the two axis P.I.O. That's unacceptable for shipboard use. Definitely a Level 3. Cooper-Harper 8. You've got to watch what you're doing or you lose control of the vehicle.

PILOT A: 10 — Minimal damping. Attitude. I've just got to get out of the loop in order to stop the oscillation, which means that you are already in a non-acceptable situation around the ship. You may be looking at your first 10! I would hardly call that acceptable touchdown attitude. Continual two axis P.I.O. Cooper-Harper 10. You get wrapped up on what you are doing in close confines you just lose it, you are in about a 45° bank to bank P.I.O. Cooper-Harper 10. I don't want to see that around a ship.

PILOT B: 10 — Whoa! Wow! This is a crazy system. I don't know what's wrong with it. It's not damped at all. I think it's an attitude system. It is an attitude system and it's just not damped. I'd give it a 10.

PILOT C: 9 — Gee, I'm sorry I said anything about damping to you. I'll go ahead and make a run but just to kind of see if it is, you know, it is in the 9 category because of the damping -- it is just way too low. Extremely lightly damped. Okay, that's a 9 and the reason for the 9 is the damping is way too low. And it is extremely tight in terms of frequency. It has a nice high frequency but the damping ratio is so low that it is continually pitching around and it is just the perfect set-up for a P.I.O. situation. And it really does require compensation to retain flight path control...

CONFIGURATION TR12
$K_{ss} = .017$ rad/cm

PILOT A: 5 — Poorly damped attitude system it seems like. And I got into that stabilized position but then I climbed. Let's see if I can get this thing back down to some reasonable altitude, here. Okay, we've got a relatively poorly damped -- not horribly bad, but it is not a zero. It is pretty low damping. Both axes. Response is relatively quick. My control inputs are very very small, but with the fast response, you know, you can -- that cuts both ways. You could get into a P.I.O. without too much trouble. On the other hand the airplane is quite controllable. Okay, the system we've got -- attitude system. The damping seems a shade low. I'm stablized over the gun deck moving up over the hover pad and a little higher than I want to be, coming down. Okay, sensitivity seems about right. Damping is just a tad low. At a stablized position. Touchdown. Back up. A little bit off-center on that one. Oops, didn't mean to touch down that time. The only complaint with that system is the damping is down a shade. Sensitivity seems very nice. Appropriate for the task. So, it doesn't fall in the category of desired performance. I would desire to have damping higher and I can't do anything about that, of course. So what have we got. Well, it is annoyance. And I would call it probably objectionable. And so I will give it a Cooper-Harper 5. Attitude system.

PILOT A: 9 — Attitude system. Fairly sensitive and shade low on damping. Got a good lateral P.I.O. there just before touchdown and a little bit longitudinal P.I.O. on lift off, don't like those tendencies. If I adopt a little bit of the same control strategy I used in the rate system, sort of a bang-bang control, I have a little bit better luck with this one. I don't seem to.... spoke too soon. I was going to say I wasn't going to excite that oscillation but there it goes again. I wouldn't be real enthusiastic about that much lateral activity in close confines on a ship. Got a question of a Level 2 or Level 3. The damping on this is putting it borderline between Levels 2 and 3. Getting a lateral P.I.O. situation fairly readily and that is not something that would be neat to have around the ship. It's a controllability question. I'll give it a Cooper-Harper 9. I don't think you can tolerate that level of damping in a shipboard task.

PILOT B: 9 — Damping is very poor on this. It's an attitude system but it's just too loose for me. It needs to be damped more. Response is very tight but you cannot precisely use this particular system because it just sits here and

I P.I.O. both laterally and longitudinally. You need some sort of a dead band or something with this particular system because it's just too tight. You can see them just sitting here in a lateral P.I.O. and a longitudinal P.I.O. at the same time. I can probably land it. I'd give that about a 9.

PILOT C: 5 — Okay, that one is a 5 and the damping is very marginal but the tightness of the higher frequency of the attitude response makes it pretty controllable. And you can't be real aggressive with it for fear of exciting the oscillations. But if you treat it pretty carefully it is flyable and you can get it on the deck with some consistency. And so I think the adequate performance requires considerable compensation is the appropriate descriptor of it and therefore it is a 5. And it is definitely an attitude system and its main deficiency is its damping is too light.

CONFIGURATION TR13
K_{ss} = .069 rad/cm

PILOT A: 9 — This is one of them underdamped rate ones. I think we've got about a 10. I'm not even going to go close to the boat. 10. I can't -- it's rate and I can't get anywhere near the ship with that one. Intense pilot compensation is required for control, I'd give it a 9.

PILOT A: 7 — Okay, you've got an attitude system. The damping is down a shade but it's not totally gone. And as to rate her -- I'm not even sure. Oh, damping is about 2/10ths I guess. It's going to be unacceptable also. Interesting! Okay, that's also going to be unacceptable for shipboard use. Marginal controllability if you get in close confines, you can drive the thing into two axes P.I.O. quite easily. It's not so much the pilot -- considerable pilot compensation is not required for control. It's just that if you try and do the job, you can't, you get in trouble. So, adequate performance is not attainable, period. Controllability is not a question -- you can control it but you can't do the job at the same time, okay. So, Cooper-Harper 7. Attitude System. Underdamped.

PILOT A: 9 — Rate system -- low damped. I find myself adapting the strategy that a lot of the AV-8 pilots do use and that's sitting there rattlin' the stick around neutral and that sort of guarantees that you don't leave an input in inadvertantly in one direction. So you're just sort of stirring the thing up continually. You've got to adapt. It is a little non-standard. Bing Bang -- Biff Bam control strategy here. Just rattle the stick around to guarantee that I don't inadvertantly excite an input that I don't want. And any time I try to make a large correction in a hurry, I've got a problem. Okay, one of the problems is that the response -- the sensitivity is quite high and the damping is quite low. I don't know which of them is causing the most problem or if it is a combination of both. You really got to stay on top of this -- almost, you know, like you're balanced on the head of a needle or something like that. I didn't really mean to touch down there. Yes, there's a good sized P.I.O. going. Okay! Well, what have we got? I think controllability is a question on a configuration like that. I personally don't think they're acceptable for support use -- Level 3 just on the virtue of that. You can certainly get into trouble close to the ground. That last time I got into a fairly good longitudinal P.I.O. close to touch down. I can't get well what was considered anywhere near an adequate level of performance. And I really think you could lose it. So, let's go with a Cooper-Harper 9.

PILOT B: Whoa! I can't fly at all. No way.
10

PILOT C: Whoa! Better go back because that one just went bananas. Doesn't like it. For some reason it is just going wild pitch down -- it just pitches down very rapidly off the blocks here. Oh, wait a minute. The stick sensitivity here is about infinity. Turn this baby off, here. That's the problem. There is an ... you can go back to I.C. -- I've lost everything here. It's got incredible stick sensitivity and it -- wild excursion in operate. It would be a 10.
10

PILOT A: I wonder where the damping went? That attitude system has damping at about .15, .2, somewhere in there. Well, maybe not. Maybe it is just a little over sensitive. It feels underdamped. Quite easy to excite yourself and lose the longitudinal and lateral axis. Real high sensitivity, low damping, fast acceleration is a bad combination. P.I.O. looking for a place to happen. Okay, the damping is low -- let's call it 0.2, somewhere around there, 0.3. Sensitivity is very high. Well, this combination of sensitivity and acceleration is very high. It flys very much like some of the rate systems. You've got to sort of mill around the neutral point on the stick. That rapid response is easy, you know, get in one of these situations. Okay, so we would have to say that you could do the job but the -- you've got to really lean on it to stay out of trouble. The sensitivity -- the combination of high sensitivity, fast acceleration and low damping brings controllability into question. You've got to -- you've got to stay ahead of the airplane and consider very carefully what you're going to do with the control in port or you could lose control of it. So I would have to give it a Cooper-Harper 8. I don't want to see that around the boat.
8

CONFIGURATION TR14
K_{ss} = .069 rad/cm

PILOT A: 4 — Deadbeat slow response. Attitude system. Hard to get in trouble with these things unless you get closure speed that you can't stop. You don't have the P.I.O. type tendencies that I've seen in some of the other configurations. What you have is to worry getting a closure rate going that you don't stop before you hit something. The airplane comes across as just as being just as stable as a rock and I ought to be able to do a very good job of this although it will take me a while. I can get into a very stable hover. The problem with it is I just didn't get into a stable hover exactly where I wanted to. I've got to get up there in order to get the attitude reference I need to stabilize. I think the basic problem is same thing I was seeing in those rate systems. You really don't have a real good feel for the attitude in here. So you've got a little display bias, but on this one I can get what I consider desired performance. I've got to stay on top of it in order to do that because the rate buildup and sensitivity is a little bit lower than I would really like. I'll give it a Cooper Harper 4.

PILOT A: 7, K_{ss}=.138 rad/cm — No lateral control until about five seconds into the run. It's a really sluggish rate system I think. Everything goes good when I get down around that super structure and I just loose the attitude and I don't know where neutral is. Oh, boy! Seems we've got a rate system with a sensitivity down to something reasonable. So what I'm trying to do is not use the HUD but just try and look outside the airplane at the pad and see if that helps any. It almost did but not quite. I'll see if I can stabilize the airplane in some sense. Here we go. I'll just get the nose down a little bit and try to get it moving and we're out of time. Oh, boy! Wish I knew. It's a basically pretty docile rate system. I just cannot come anywhere near the level of controllability that I need to put the thing down on the spot and that's primarily due to a lack of cues. I don't know where neutral is. I'm either too high or too low or too much wing down and I just don't have enough repro cues nor acceleration cues and I just can't do it. Give it an upper 6. No wait a minute. I think it's worse that thet. Upper 7 if I can't do the job with those systems.

PILOT A: 7, K_{ss}=.034 rad/cm — Another attitude, Very sluggish. I don't know if it's sluggish or no sensitivity. It's one. I think it's both. These airplanes are very stable. I see with the shipboard use that you develop inadvertant or

inappropriate rate. There's no way you can stop it before you run into something like the ship. I'm on a vertical oscillation there. I'm not really sure that the captain of this destroyer would be enthusiastic about me making roll on landings. That would be the only way it would be at safe bringing some of these things aboard. It doesn't really have sufficient response to keep you out of trouble if you are so unwise as to get into it in the first place. It's an attitude system. Sensitivity is down and the acceleration is down. Give it an upper 7. You can get the job done but you've got to stay well ahead of the vehicle. There is a compound problem here that although I can do the job as it's defined, I wouldn't go anywhere near a real ship with something that reacted that slow.

PILOT B: 7 Too sluggish. It's an attitude system. It's just too sluggish. You can fly it as long as there aren't any gusts or anything that is going to cause you to require any quick changes in attitude. You could fly with no problem but I'd be afraid of gusts and things like that with this system. I gave that a 7.

PILOT C: 6 Okay, that one is a 6 and the main motivation in calling it a 6 is that I think you can get adequate performance in this task but it requires extensive pilot compensation. By adequate I mean you can get it on the deck within the time allotted with some practice. But I feel that the attitude is much too loose and it is strictly a Level 2 airplane. Precision attitude is really not possible but there is enough control there where you can at least marginally get it on the deck. And it is an attitude system. And I should add all of these have adequate -- appear like they have adequate damping, they are just sluggish. And so it is difficult to make a precise small attitude change and nail it, because it moves so slowly.

CONFIGURATION TR15

K_{ss} = .069 rad/cm

PILOT A: 7 — Very sluggish system. Got my 15 feet. Approaching the fantail, over the fantail, over the gun, coming up on the pad, still trying to maintain around 15 feet. Doesn't answer to the helm horribly rapidly. I stopped a little short of the pad inadvertantly. Trying to keep my speed down. Kept it down. Kept it down a little bit too low and ran out of time. Got my altitude. Coming up past the fantail over the gunner post, over the pad. I just can't stabilize this turkey. Unacceptably slow. No problem with the control, just not adequate for the task. Cooper-Harper 7. Just can't make it go fast enough.

PILOT A: 7 — Controllability is not so much a question as I can't attain an acceptable level of performance. I just can't make the thing stop moving. So Cooper-Harper 7.

PILOT B: 7 — This is an attitude. No it isn't. It's a rate but it's damped. It's a lot better damped than the other one. I think it's a rate system. It is, isn't it? It's damped but it's again -it's sluggish. There's not enough -- I don't think there's enough response left in this thing to be able to get you out of trouble if you ended up in a real gusty situation. I think we've got kind of a problem here. We need it damped but yet we also need to be able to get the response to correct the gusty wind condition. It's going to be kind of hard to do I think. I'd give that another 7 just because there's not enough response for gusty conditions.

PILOT C: 8 — Call that a rate system, and it is still kind of sluggish. It's a rate system but it's sluggish -- not a snappy rate system at all. And so control of flight path is still a big big problem and I find myself -- really the best I can really do with this is to kind of stabilize in a hover behind the ship. Once I get over the deck and I start losing my attitude cues I can't handle it, but I can hover in behind the ship and kind of maintain station back there. So I guess it would be an 8 because I can't land it. I can't do -- I don't have any control over the deck. So, for this task this system would be an 8 and I believe it is because I just don't have the attitude cues over the deck to stabilize this particular set of dynamics. So, pilot rating of 8.

PILOT C: 5, λ =2.0 rad/sec — I probably got lost on the deck. Okay, that one is a 5 also. It is an attitude system and it is not that sluggish. It is still sluggish. It comes into the sluggish category but is is mildly sluggish but the

$K_{SS} =$ .0035 stick sensitivity seems low and so there is an awful lot of stick activity to get any action out of it. And I think the primary reason though for the 5 is the sluggishness of the attitude. For approach it's great. It is a 2 or a 3 on approach. But when you get up over the deck and try to hover you just need a lot of precision, a lot of attitude precision for that very small area. And for this task as it sits doing a hover over the deck I believe it's a 5 in hover and a 2 on approach, and an attitude system.

CONFIGURATION TR16
K_{ss} = .069 rad/cm

PILOT A: 4 — Well, you've got a situation that I'm not quite sure is normal. You've got fairly substantial cross-wind components from either direction. That's not realistic. You get a lot, you know, your ship's making some wind. So, essentially what you got is 30 knots of wind coming up over that -- the top of that thing and spilling. Okay, bring it in and try to stabilize over the gun deck. Okay, it's stable position, moving in over the hover pad. About 20 feet altitude. Okay, 10 feet and about 20 feet to go. A little short. Okay, I touched a couple feet short - my problem, not the dynamics. The dynamics on that one are relatively docile -- that's the rate system -- the attitude system, rather. No particular problems with it -- it goes where it is pointed. Response build-ups and what have you are satisfactory. You have to sort of stay on top of it. It is a fairly difficult task. I doubt you're going to see very many level one's with this task. I'll give this one a Cooper-Harper 4.

PILOT A: 4 — I've got another attitude system. Well damped - over-damped -- sluggish response. But pretty damped stables. Oscillating a little bit on the throttle. Coming up to the stable hover position. I didn't mean to lose altitude there. Can't quite stabilize. If I take things nice and slow -- it is as stable as a rock. Doesn't cause me any problems. I want to see if I can get into trouble with it, though. Okay, overall that's not too bad a system. Damping is good, it is as stable as a rock. Sensitivity is a bit low. Just run it with that low sensitivity. If I could get a closure then I couldn't stop, but it doesn't seem to be a problem when you adapt to the sensitivity. So, I wish it had a slightly faster response. However, I'll have to give that a Cooper-Harper 4. I can certainly get adequate control out of it.

PILOT A: 3 — Attitude. Fairly brisk response. Don't seem to have an oscillatory tendency. Got stabilized hover over the gun. About 10 feet altitude, moving up over the hover pad. Controllability seems pretty precise. I'd like to see it again. This may be a Level 1. Got a basic attitude system. System is well damped. Sensitivity seems good and the acceleration is good. Cooper-Harper 3. This is the best one I've seen.

PILOT B: 3 — This is an attitude system with a lighter touch to it; less damping. Let's see what we end up with. Good response as far as being able to develop a roll rate quickly. I kind of like this one. Takes me a while to

figure out what it is I'm evaluating here. I kind of like that. I'd give that about a 3. Good response. The damping was not overwhelming and I think that I like the attitude system better than the rate system in the hover. That was very nice really. Controllable with good response.

PILOT C: 3.5 That again is a pilot rating I believe 3-1/2 and it's 3-1/2 and possibly a 4 and the only reason we're dropping to the 4 would be flight path control and I believe that I might be a little critical there because I'm used to helicopters that have excellent heave damping and so my background -- kind is that I'm not used to having to work so hard on flight path control. Although, I guess by STOL standards this would really be quite good, by powered lift standards. But the attitude control on this is quite good and, is a 3 for attitude control and a 4 for flight path control. So the overall would be a 3-1/2 and it is definitely an attitude system, and I wouldn't call it crisp and I wouldn't call it optimum, but I'd say it was definitely in the acceptable range.

CONFIGURATION TR17
K_{ss} = .069 rad/cm

PILOT A: 9 — This is one of them overly sensitive rates, or is it an overly sensitive attitude? I think it is attitude. Fairly high sensitivity. Barely a little damping. Attitude system. You've just sort of think about where you want to go. Like a Pitts. A little P.I.O. in the lateral direction. I've got a touchdown but it wasn't quite where I wanted it. This is unacceptably sensitive. I've got two problems. You've got a real high sensitivity very low damping. You are always down there where you are just sort of leaning the stick against the breakout. So you've got an implementation problem, the smallest possible input that you can get into the stick is too much. Very easy for this one to get away from you. I won't say control will be lost but you've got to really watch what you are doing to retain control of the airplane. Intense pilot compensation. Give it a 9.

PILOT A: 9 — Damping is about a tenth or a less. It's an attitude system and I just don't have the visual references sometimes, and I get into one of those horrendous attitudes. Oh, Lordy! This is unsafe. You've got underdamped system. It seems to be attitude. Very high sensitivities. The combination is very bad. I wouldn't be real enthusiastic about flying this thing in any task that I can think of. Much less a demanding task.

PILOT A: 4 — K_{ss}=.034 rad/cm — Feels like one of those stable as a rock attitude type systems. A little bit of longitudinal oscillation. I can do a roll on okay but I can't get any success with a hover. This is a pretty decent system. Sensitivity seems fairly good. Acceleration could be a shade better. I'm having success with this. I wish I had slightly better cues but I can certainly put it down where I want. A combination roll onto the first one but I actually got to the stabilized hover. So I can get the desired level of performance by working hard enough. Cooper-Harper 4.

PILOT A: 10 — K_{ss}=.138 rad/cm — Sensitive attitude. Underdamped. It takes almost nothing at all to get a P.I.O. going here. Stop. This is unacceptable. I've seen enough. Ten.

PILOT B: 10 — I'm not going to be able to fly it. That's a 10. It's just too loose.

PILOT C: 9.5 — Just sitting here flying it I'll make some comments while I'm flying it -- it appears to have an excellent attitude control system but the stick sensitivity seems to be off by a factor of 10. I'm just guessing that's what is going on -- that it just seems like I've got a good attitude control with extreme stick sensitivity. But we'll go ahead and fly this if that's the configuration you want. No! That one is pretty obvious. Okay, big attitude control problems on that. It appeared to have a very high frequency attitude system but I could not get any precision attitude control. A lot of pitch bobbling -- I recall almost bordering on a tendancy to P.I.O. -- if it -- P.I.O. probably isn't the right word because I never got into a sustained oscillation. But definitely could not change pitch attitude with any precision and if I wanted to change pitch attitude I would say 5 degrees I wasn't able to do that. It overshoots it and of course if you can't do precision attitude changes you certainly can't fly a V/STOL. And so my -- I call that a nice solid 9-1/2. And I hate to second-guess things because when you're flying them you really don't know what's wrong but I'm going to say that it felt like the stick sensitivity was extremely too high. It was at least one of the problems with this configuration.

PILOT C: 3.5 K_{ss}=.034 rad/cm — Okay, I'm going to give that one a pilot rating of 3-1/2 and I think that pitch and roll attitude control is good and much better than the previous ones which were quite sluggish and this had complete control over X and Y position is far superior than any of the others. The only reason it's not better than a 3-1/2 is altitude control which is reasonable, but still requires a lot of attention. Let's see...stick sensitivity is just about right for that one and again the flight path response is a bit of a problem, while the heave damping is reasonable, but it still does require some attention. Oh yea, and the other thing I should mention is that starting today based on John Clark's comments I've kind of initiated a new procedure and that is I'm approaching, I guess, the way it's really done along one of these center lines on the back of this ship on the drop lines, so that's a little different than the approaches I made yesterday which I came in directly from the stern and this is definitely an attitude system.

PILOT C: 5 K_{ss}=.017 rad/cm — It's squirrly. Seems a little loose on the altitude control. You can do some pretty precise corrections for this gain level. I think it could get away from you, though. That's not too shabby. The altitude

control seems to be a little bit looser. Yes, that's pretty sensitive. Okay, what do we got? Well, we've got a very sensitive attitude system and you can do some pretty precise maneuvering but you've got to stay on top of it. You've got to compensate for that rate. With that kind of rate and with the -- the rate available -- and with the build-up on it you can get fairly precise control. But you've got to work at it to avoid over-correcting. You could, in close confines, obviously you wouldn't want to see one of those sixty degree wing drops like it did at the last. So, I would have to say the controllability is good but you have to compensate in order to get that. It is definitely in the Level 2 area because of the high sensitivity. I'll give it Cooper-Harper 5.

PILOT A: 5 K_{ss}=.034 rad/cm — Very very quick responding. Maybe too quick. Okay, that's a shade brisk. It would be uncomfortable in flight. The dynamic response is too rapid. That's offset a little bit by, you know, that coupled with the high static gain would be disastrous, but the gain is appropriate -- reasonably appropriate to the rate build-up. I think you could get into trouble with this if you got too rambunctious with it or tried that one visual approach and get into a longitudinal oscillation. You know by overdriving it. As long as you stay with it and compensate for the brisk onset and realize it is there, it is no real big problem. I think you could have problems with it so I'll go to a Cooper-Harper 5. The rate build-up is just a little bit too rapid on that one. It is an attitude system also.

PILOT A: 2 K_{ss}=.017 rad/cm — If your object with some of these things is to confuse me ... you're certainly doing it. Yeah, this one flies like an attitude system. And like a good attitude system at that. You may have yourself a 2. I like this. This is a Cooper-Harper 2. It's attitude. Everything is good. You don't a...you don't have to provide too much compensation on it. You don't have to lead it, you don't have to lag it. It just does what you tell it to do and there's no fuss about it. The blend and the gain and the dynamics are good. I don't feel like I've got too much gain, I don't feel like it's a...I have to over drive it. Everything just seems to work out nice.

PILOT A: 2 K_{ss}=.017 rad/cm — The attitude system is a good blend between gain and dynamics. I really like it. Cooper-Harper 2. That's a good system.

PILOT A: 2 K_{ss}=.017 rad/cm	This is one of the good ones again. Okay, it's an attitude system. It doesn't have too many bad habits. You got a good blend of sensitivity in the gain. Something is vaguely annoying, but I'm not quite sure what. I like it. Cooper-Harper 2.
PILOT A: 6 K_{ss}=.034 rad/cm	Static gain is very high. Sensitivity is extraordinarily high. It would be easy to get into trouble with this one. It ignores small inputs but certainly overly responsive to large ones. The problem with this one is that it's easy to get into this kind of situation down close to the ground which is not really desirable. You'd see all the sailors jumping overboard down there. That's just sort of a P.I.O. waiting for a place to happen. You have to lean on it to lose control of it. On the other hand you can get into a P.I.O. if you get a little rambunctious or don't pay too much attention to what you are doing. That sort of leaves me in a bind, I don't know if I want to say controllability is a question or that you've got to stay on top of it. If you stay on top of it you can get adequate performance out of it. By staying on top of it, you've got to avoid getting into a high gain situation. Give it a Cooper-Harper 6. Very objectionable, but if you stay on top of it you can fly it. Attitude.
PILOT A: 4 K_{ss}=.017 rad/cm	Maybe just a shade high, sensitivity is not too bad. Somewhere between a 2 and a 4. It's an attitude system, dynamics seem good, static gain is a shade on the high side. Certainly can get the desired level of performance. Tolerable (pilot) compensation. Problem is there is just a shade too much there. I'll go with a 4. I'd like to see that one toned down a little.

CONFIGURATION B116

PILOT A: 3,9

Okay, nice smooth transition. When it started moving again in this sytem I've got much more sensitivity than I had out there on the approach. So, I've got the possibility of a longitudinal P.I.O. I've had absolutely no trouble laterally. It is just sort of dead there. Again I get the sensation that I'm in a sideslip. I didn't quite mean to stop that far out, alright? I could barely discern the ship that time. There's no attitude bobble or anything, and, you know, sort of keep track of the speed you're at. It is a nice smooth transition, but what I was interested in is if I could force that longitudinal P.I.O., I don't really think it is a major problem. Okay, I can stabilize -- move in over the pad. I like this system. The final system is nice in responses. The initial system has got no particular maladies. I guess in the end, in the final attitude system I like to have just a shade more rapid response -- not too bad. Okay, now this is something I've seen before. This is something that could really cause you some serious problems. The -- is the final rate system the same as the initial rate system? Oh, okay, now from the inital set-up you don't have to make any large amplitude flight maneuvers. There is not any large corrections to be made. This is a very nice docile task and it is very easy to start it in that flight condition and stabilize the attitude for the speed and then part of the glide slope will start on down. No big deal. You get down in the transition you know you've got to sort of lean on it to get the nose up. It is not horribly overly sensitive or anything else. The blending between the two systems is nice. I've already commented that I would have liked maybe a shade more response from the attitude system in close. But I didn't have any particular problems in getting the performance that I wanted with it. It's -- in the back of my mind I would like it to come a little bit faster. Get in -- sit the airplane down and go around -- accelerate, and then when I make that turn out, now I notice it is taking a long time to blend between the attitude and the rate system. So now I'm in this turnout -- I'm doing 30 knots or something like that. I've got to hold the stick over there to keep the bank attitude I want and then after what seems a long time all of a sudden I get a shift in the rate system, the nose drops, and now I've got to pull that stick all the way back in my lap just to keep the nose from going on down farther. And now I notice that the rate system -- I'm in, in this large amplitude maneuver with the nose tucking on me is very very sluggish. I would hate to make that transition on a dark night. I think I would crash.

What I think you need is -- I think you need more sensitivity on the rate system on that particular one. So, let me break this up and say that the initial part of the task, all the way down to and including the landing -- I'll give it a 3. You really don't have to work too hard at all. It was very good down to that point. Everything nicely tuned to the task. The go-around, however, you've got to compensate to keep control. And on a dark night with no horizon out there I think you would lose control. So that go-around is a 9. But I'm not going to give you an overall rating. There is too great a discrepancy between the tasks.

PILOT A: 7,10 The first control is -- of being very stable out here. The thing is you just don't have any response. So, until you try to force it to do something you don't notice it. You can put it someplace and it will stay there. You can use a lot more rate available out in this area. If landing between the systems is transparent, it's very nice, very easy to adapt to. That's unsatisfactory. The -- on the approach and on the go-around the available rate in terms of degrees per second per degree is inadequate. On the go-around, it is particularly noticeable and it is almost -- 20 to 25 degrees, in fact, you've got full aft stick to keep the nose up. You need much more getting up there on the go-around. Now, on the approach you don't notice it as the sensitivity so much as you notice the sluggishness. Very very slow response. However, that's not a major problem -- it is a deficiency, but it doesn't really cause a problem on the approach. So the -- for the approach task you can get adequate performance out of it. You certainly want it to be a lot crisper. I'll rate the approach as a 5. The transition is good, you know, given that you want just -- is that a good transition or not? Well, yes, it's good. It's unnoticeable to the pilot. The attitude system that you arrive at over the ship though is totally inadequate for close confines maneuvering. About the only successful way to make an approach of that would be to roll on out I believe. So, the attitude system -- you can't hover, for sure. Particularly with any external disturbance. Controllability would rear its head in close confines. You could very easily let a situation develop where you did not have sufficient response to stop it. You got to really stay ahead of it to prevent that. However, I won't say that it is a controllability problem so much as a response problem. Just say you cannot possibly get the performance you want. Give it a Cooper-Harper 7. On the go-around it is totally inadequate on the rate response. That's going to have to be a 10. The go-around, you notice the blending. It takes a long time to come in and pretty fairly suddenly it seems

like you drop into that rate system. If you happen to be over banked at a time -- at that time when you run back into the rate system you've got a problem because you'll never get the nose up. That's gets into the 10 also. You've got the problem that on a dark night with no horizon, without a level of control, you would lose it. You would go right into the water. It's not a problem of the blending schedule, per se, it is a problem that when you drop into the dynamic -- the rate response, you haven't got any controllability. You don't have adequate controllability. So, you know. No matter how you made that transition, you would have problems.

PILOT C: 2,9 The blend on the approach, I never noticed it. So I have to say the blend was a 2 coming into the approach because I never saw the thing blend and that's certainly negligible deficiencies and pilot compensation is not a factor because you don't even see it happen. On the departure though, the blend was unacceptable. It was a 9. It required full back stick. What happened is you picked it off the deck into a hover and then started an immediate left climbing turn and accelerated. At the blend, the nose pitched down to the point where I had to use full aft stick to keep from just diving into the water. Then when I rolled the wings level, I had full aft stick and the thing started to climb straight up. So it's really a handful during that turning, accelerating departure from the ship. So that would be, I think, a 9. And in terms of the rate system coming during the approach, just as a side issue, that seems to be a pretty reasonable rate system but it's still a little sluggish and I'd say it would be about a 4 because it's not a real snappy rate system. The attitude system, as far as it transitions to, is too sluggish and I think that would be a 6.

CONFIGURATION B121

PILOT A: 4

Hangs on to the attitude system for a long time on the retransition. Okay, I liked the sensitivity and rate of the attitude system to be up just a shade, but also it's not too shabby. I don't have too much problem with it. I can stop it. I can't perceive a definite transition point. The blending schedule's fairly nice for that system. My only hang up because I wish it had a slightly faster rate of build-up on the attitude system and/or slightly more sensitivity. I certainly get the job done with it. Cooper-Harper 4.

CONFIGURATION B122

PILOT A: Excessive lateral sensitivity. Insufficient longitudinal sensitivity. P.I.O. prone. I'm still in an attitude. Now, I'm in a rate. (end of tape) Pilot commented the blending schedule was too long.
7

CONFIGURATION B124

PILOT A: 6

There is an area in that blending schedule where you're neither fish nor fowl and you're not quite sure what you're flying and it doesn't have enough response. Let me see that one again. I don't know why I'm sensing that but in the range of transition -maybe it's a shift in delay or something like that -- there is a period of time there where I feel like I've got almost no control of the vehicle. It's just no response is there and I find it quite disconcerting. I think I can get into trouble with something like that. Now the control is there, you just have to lean on it harder and I'm not really sure what's happening. That particular blending schedule I don't find acceptable. I can tolerate it. Get the job done. It's a major deficiency in there that you really feel that you don't have any control. I'll give it an upper 6.

CONFIGURATION B125

PILOT A: 7

That's better. Well, I still wish things happened a little faster. Well, about the same thing as I've seen before. Things just don't happen quick enough once you transition and you can get into trouble. I did touch down inadvertantly a considerable distance from where I wanted to. I get sort of a helpless feeling when I get a closure rate built up toward that super structure. Just wind up having to pull the thing right back in my lap. So, the rate at which things occur in the attitude system is deficient. It's not adequate for the ship. Cooper-Harper 7. Transition itself blending between the two systems is essentially indistinguishable. In this case, it's not a matter of harmony. The harmony doesn't bother me. It's the attitude system -- does not have adequate response. It's not safe around the ship.

CONFIGURATION B136

<u>PILOT A:</u>
10

Seems very stable out here even though I've got a fair amount of longitudinal sensitivity it seems like. A bit of a tendency to overshoot and oscillate due to the slow acceleration. Not too shabby. Blending is relatively undetectable. We're back to that good attitude system that I like. Well, I don't know. I got a little oscillation in here and I'd say the attitude system is a little more sensitive. Certainly gives you the opportunity to get out of trouble. A bit much sensitivity on the attitude. Retransition is no problem. There it goes. It takes a long time to transition and when you do get it you get sort of an abrupt nose drop. Some of the configurations when that nose goes like that I think you could lose it. This one you can compensate for it. If you're tender with it on the approach that thing seems very docile and controllable out here. I've got no major objections to the approach dynamics. Transition is pretty transparent and I guess one of the reasons is the sensitivities seem to be relatively well matched although this eventually develops into a relatively sensitive attitude system. Is the blending in this one taking that long? Is that what I'm seeing? (Blending takes 15 seconds.) That's what I'm seeing then. I'd like to do this one and try a different technique here. Because that level of sensitivity is a little weird. So the problem is that you've got--during the time you ought to be setting this thing down you're never able to settle down in a control strategy. Just about the time I think I got it licked, I realize I've got a very sensitive airplane. As long as you watch what you're doing out here. No big deal. Interesting. Using one control strategy. It's just not that shabby. Using a different one it's a 10. Isn't that interesting? Okay. I've seen enough of that. The rate sensitivity is--I wish I had a little more but it's okay as far as rate. Considering the air speed, the rate's not too shabby. The rate of buildup, roll mode time constant, in particular, is totally inadequate. Three seconds, four seconds, something like that. As long as you stay ahead of it on the approach that's not a major problem. I would hate to try and do it with that kind of roll system given that I had rolling gusts or something like that. I think it would be a different story. So on the initial approach, yes they have it for sure. But the work load is not horribly heavy. I give it a 5 on the initial approach. The transition is relatively undetectable initially. You never notice any abrupt change in behavior. It seems like a relatively docile transition initially. The attitude system that you eventually wind up with is very sensitive. All by

itself it's pretty controllable. However, you could get into trouble with it so I'd say that one would have, on the attitude system that you wind up with eventually, is a little overly sensitive and you've got to stay ahead of it or you're going to have some problems. Certainly you can get adequate performance as long as you remember what you've got. So I give that one a 5 also. Now, let's get back to the transition. The initial blending between the two systems, as you shift over from a rate to an attitude, is not too shabby. It's relatively transparent. However, there's an area in there where all of the sudden-well, not all of the sudden. You slow down. You've made a nose change and you've got the nose up and everything's good. You go to put the nose down and wham. You've gone to an overly responsive system and you say, "Oh, My God," you pull the stick back and you know what happened now? You've got about 90° straight up. It's a shift in sensitivity between the two systems. Even over a period of time there is an area in there which you will certainly lose control if you don't happen to get lucky. So I'll have to say that's a 10. That's the transition.

CONFIGURATION B143

PILOT A: 3 — It looks like an attitude system. Transition into and responses seem reasonable so far. Controllability is fairly good. I've got this feeling I'm flying sideways. The blending is very good and no problems with controls and the transition. It's an attitude system. It's fairly easy to control. All told, it's sort of a nice system. The blending schedule is nice. This is an unusual attitude. You've got a fairly severe nose down attitude and you're really, really climbing. Neat. Okay. The attitude system that it transitioned into at the end is docile. It's well damped. Sensitivity seems adequate. No tendancy to get into trouble with it. It's very predictable. There's still something that disturbs me about the initial approach in that when I yaw for the course and drop the right wing to move sideways, I seem to pick up a left velocity component; beta or something like that. In other words I don't seem to be going where I'm pointed. I'm moving in that direction but I'm not sure I'm moving as fast as I should. It could just be the speeds are unusually low. I really don't have that much of a handle on it. I'd have to give that transition itself a 2 or a 3. It's super. I give the transition a 3. The overall task I give a 3.

PILOT B: 8 — I don't much like the rate system at all. It just seems like there's a lot of wandering around directionally for some reason. It just wants to--it just moves back and forth. It's poorly damped. Okay, now we're in the attitude. I like the -- the response is not that bad. Fairly good response. You're going to have to give me some more time if you want me to look at the acceleration. Looks like you're changing it at 15 knots. And it is not an objectionable change, all in one quick switch-over there. I don't find that objectionable at all. I didn't even see a change over there. Now on this one I just won't even bother to go on the ship. I've seen that part. Okay, there's so few cues out here on the acceleration maneuver, I think it's difficult to tell exactly what's going on. You can reset. I didn't find it objectionable. The transition -- I didn't even notice it. But it's mainly because I'm -- I think because I'm looking out here at a black hole and there's no real good references out there except maybe a star to tell what I'm doing. You might be better off for these purposes to use a daylight scene of some sort or another ship out in front of you, or something else. I would rate that as about an 8 before the transition -- I don't like the rate system. I'll give that about an 8 and I give the

attitude system about a 3, and I'd give the transition, you know, no problem with the transition from one to the other. It looked like it was almost an immediate in the decel and a slow transition in the accel. But I really couldn't tell on the accel.

PILOT C[2]: They've got these big steps in the display occasionally. Just all of a sudden moves. Okay, there's one. Oops. Okay. Okay, I guess I'd like to give a couple of different ratings to things. First of all, I guess the primary thing we're talking about here is blending and I'll have to say the blending must be good because I can't even feel it. I can't tell when it blends from one system to another, or even what it is blending to and from. So, the blending is not a factor in the flying of the airplane at all that I can tell. And, I was very aggressive on the acceleration away from the deck and I couldn't feel anything coming in or going out. Okay, so the rating on the blending, if you want a pilot rating I would have to say 2 because I can't feel anything. But then as far as the task -- doing the task goes -- on the approach before I get into hover, the heading control I find to be a big problem and so I'm not sure what's going on there. If it is adverse yaw or excessive roll sensitivity. It seems to be extremely sensitive in roll. And the roll dynamics are not that good, so I was spending a lot of time getting that straightened out. And then as I get down close to the ship my heading problem seems to go away and I seem to be blending into a system that I can fly better. And so it is -- far out -- I would say it is like on the order of a 6 and in close near hover it is more like 4-1/2. Still kind of a loose system, but not bad. And that's directionally. As far as pitch goes I don't really notice that much difference in the pitch axis all the way in and so I really have to say all the way in the pitch is on the order of well, 4-1/2 also. There's no change.

CONFIGURATION B223

PILOT A: 7

Okay, what have we got? The final system you wind up with is insufficiently responsive for shipboard use. The initial blending schedule is indiscernible. I think I noticed a little jump in there, but all in all the initial blending from the initial approach rate system to the final attitude system is not too shabby. However, on the retransition -- boy, I'd hate to do that on a dark night on instruments. It takes an absurdly long time and then to make the transition and then almost abruptly you've got a rate system. I don't like that at all. I get the job done. But I'm still going to have to say that given that you're going to be operating in close confines that you've got a potentially dangerous problem and there's a lack of response. Cooper-Harper 7. Well, that's a 7 all by itself, I think. I would hate to try that at night on instruments. But the 7 is primarily -- now the initial blending schedule is not that bad. The 7 is primarily the result of the final dynamics on the attitude system. They are inadequate for shipboard use.

CONFIGURATION B226

<u>PILOT A:</u>
5

Got some weird and unusual noises in (a glich) on that one that sort of threw (engine noise problem) me off. So this won't be a valid evaluation. I do seem to have a little bit of a longitudinal P.I.O. problem with this one. No real problem laterally. Okay, I'm still on an attitude system. I'm still holding stick. Now I'm in the rate. The retransition is too slow. I'll have to see that again to rate the initial transition. Okay, I'm getting a little bit of yaw jump there in the transition I didn't -- I was pretty close to nulled out at the transition. I guess I'm going to have to see this one again. I have a lonitudinal P.I.O. This is almost the reverse of the previous configuration. I don't have any problems at all with it laterally. Longitudinally I get in the tendency to go into longitudinal P.I.O. I'm going to see what happens when I just go ahead and get my Mach up a little bit here -- 25. Same thing -- I'm holding stick. Can you increase the time and let me see that again? Now I get that tendency to drop into that longitudinal oscillation, almost every time. I think it takes too long to blend back into the rate system on the go-around and there's an area in there where you're not really sure what you're flying. The transition schedule is sort of unnoticeable. I'm transitioning a little bit further out than I have been. So, I've got no problems with the blending. I don't like the system I transitioned into. I get into a longitudinal P.I.O. with it. It's not dangerous, it is just sort of disconcerting. I've got to sort of watch what I'm doing. The amplitude is not bad and I don't seem to reinforce it. It's just that I oscillate. So I can get good performance. I can get adequate performance. I'll give it a Cooper-Harper 5. Hedging that I really don't like ... the dynamics on the go-around.

CONFIGURATION B231

PILOT A: 3 — Again no problems on the transition. I'm sort of curious as to what happened, if you got carried away with it and could you stop it and yes you can. Even if you just haul the nose up there's no real tendency to lose track of what system you're in or anything else. So these are all fairly docile and begin. They're easier to do in the first phase. Ain't nothing wrong with those transitions. That one was very controllable on the retransition, I believe. Cooper-Harper 3.

PILOT C: 4.5 — Okay, the longitudinal control I would say is a -- I'm torn between a 4-1/2 and a 5. I would say 4-1/2. Requires -- it still requires compensation but the attitude control this time was a lot better. Again, I could not distinguish the blend between one system and another, longitudinally in the approach or laterally for that -- well, yes laterally I could tell. And the blending therefore is excellent because I can't tell it is happening. And the attitude systems both before and after the blend were around a 4-1/2. And there's -- I finally could land the thing on the ship but it still requires a lot of compensation. And then on the acceleration HUD to hover that task I could put full control in without any trouble. I can -- you know I can lift up off the deck and just throw the thing in the corner and all I see is -- I see a sudden glitch in the visual display and it looks like my turn rate it suddenly goes from a low value to a high value but I have an attitude system before the glitch and I have an attitude system after the glitch. And so I don't see - it looks -- I don't understand that. Looks like the kinematics are changing and not the dynamics. And also the attitude -- the system will have after the blend I don't like -- before the blend it is a 4 -- well, it is a 4. For accelerating out of hover, in fact it is a -- for the task of lifting up and flying off the deck in fact it is 3. So, let me up that to a 3. But then after the blend I don't have enough control authority and so I would call that about a 5-1/2 after the blend because I don't have full stick, only gives me about oh, 45 degrees of bank. And so I don't like it after the blend, but the blend itself is kind of a mystery. It just switches from one turn rate to another.

CONFIGURATION B246

PILOT A: 10

Okay. That one feels a little loose out here but I've got better controllability, a lot better than I had. A little tendency to get into a lateral P.I.O. On the initial approach, I think that level of sensitivity is not too shabby. It's a little bit overdoing it when you get down in close. We've got about one tenth damping. Okay. Let's make some running comments on this one. On the initial approach, level of sensitivity is good; out here at 40 knots or something like that. Don't have too much problem out there. It's a bit oversensitive. A little bit too much. What happens is you're getting close to that level of sensitivity down in here you start chasing things and you immediately get into this overshoot/undershoot P.I.O. type situation. So the sensitivity in close in the rate system is a little too high. You've got to keep track of what's happening. Now the transition is relatively transparent until it gets fully developed and you notice that your damping has gone south for the winter. The attitude system is a 10. The retransition is a 10. The initial approach is an 8. You've got to really watch what you're doing with that level of sensitivity in close or you develop a fairly wild oscillation. Inadequate. Too much sensitivity in close. Put on the initial part of the glide slope is not that shabby. The transition, initially, is relatively transparent. You know you're going from one to another. So the transition wasn't jerky or abrupt or anything like that. That was relatively smooth. However, the problem of course is that you wind up in a totally unacceptable system. So you go from something that's marginal initially to something that's unacceptable relatively smoothly. I don't think I can honestly give you an evaluation of that transition because you end up at the end of up with something that's totally unacceptable.

PILOT C: 2

These stick sensitivities are really high on this one. It may be so high that it's not flyable. Let me start off with the most dominant thing in that entire run and that is the attitude system that you transition to. It appears like it could be a pretty good attitude system but the stick sensitivity is incredibly high and I call it an 8. I did make one landing on the deck but the rest of them were a disaster. Anytime I tried to get aggressive at all with it it got away from me. Let's make that a 9. And I believe my perception of it is that it's entirely due to the sensitivity of the stick. The blend coming into the hover I never saw. So I guess I didn't set up that condition nose high that time and so I never saw the pitch down. So for that

run the blend would have to be a 2 since I never saw anything and I can't really rate the blend on departure because the problem we had where it seemed like the air speed went from 30 to 70 knots instantaneously and I just couldn't make any sense out of those departures.

CONFIGURATION B312

PILOT A: 7

Okay, this is the situation where I get into that lateral P.I.O. again. I'm not real enthusiastic about the dynamics at the end of that one. There you go. I feel the response in this system is something that just doesn't have too much response at all longitudinally. Laterally, it is overly sensitive. I get into a lateral P.I.O. if I don't take a little bit of care there. Okay, longitudinally sensitivity doesn't seem to be enough. There's a feeling that you got to sort of dead area in response. And then you get into this situation again. Same thing -- I've got full aft stick and the nose isn't coming up. So, major deficiencies -- Cooper-Harper 7. The going from a fairly responsive rate system to a minimal response of longitudinal attitude system and you get a feeling in there that you almost don't have any control over it for a few seconds. Compounding the problem is this lateral sensitivity that I can get into a lateral P.I.O. with. I don't like that one at all. I really didn't really notice the -- well, the affect of the blending schedule is that it sort of aggrevates the sensation of not having adequate longitudinal control. I'm not sure why. Now, on both of these I noticed that on the go-around maneuver I'm not -- I never get back into an attitude system (rather a) rate system in pitch. It doesn't seem like.

CONFIGURATION B316

PILOT A: 10 I didn't have the stick trimmed when I started out. It's a real nice control out here -- nice and solid feeling. The throttle is nice and ... doing what I tell it. I went through the transition range here more or less of a fixed attitude so I can't really say what was happening. All I can say right now is I don't like what I'm in. Insufficient attitude response on this system. It is unsafe around the ship for sure. Didn't get close enough, did I? Now why does it seem like I've got more response? If I really lean on it I can get all kinds of it. Interesting! I'll have to see this one a couple times. The same thing, I've got full aft stick. The nose is not coming up horribly rapidly. Pretty darn sluggish out here in the approach task. Sort of oscillating through the glide path -- the glide slope -- or the glide path. You've got me a little gun shy with that other one -- I'm stopping too far out. I don't want to say that this is one of those ones that may be the transition is fooling me and it is taking too long and I'm never really sure what I'm flying. Okay, that's attitude, attitude, attitude, attitude, rate. Okay, at that bank angle -- see, there goes the nose. I've got full aft stick. Now I've got wings level. I've got totally inadequate longitudinal rate response. That is a 10 guys. That is based on the go-around. The go-around on that one is a 10 based on the rate response. I'd like to see it again to rate the transition. Okay, right in there. Right in that period of time right there I've got almost no response. I've got full right stick. Now, I've got lots of it. Okay, there is an area in there where it is blending between the two systems and it feels like it is just dead and if you get into that area you don't have any response. I mean, it's just not there. You don't have any control over the ship at all. If you avoid getting into trouble in that area and particularly if you get into -- fully into the attitude system it is not too shabby in close. I could wish for a bit more response in this fully developed attitude system. Both in sensitivity. Both in terms of absolutes -- in other words, the amount I can physically get out of it. And there it goes again. 10. And the rate of build-up on it. That's on the in close attitude system. But in the fully developed in close attitude system it is not too shabby. So, the in close attitude system all by itself is -- oh, I would like to have higher rates. It means you got to believe it. I'll give it a 4 on the -- the fully developed in close attitude system. The initial approach rate system is sluggish and if you get very far off it takes you a long time to get corrected.

Fairly inadequate out there. I'll give her a 7 on the initial approach. The transition -- now, I did not lose control because I wasn't in particularly better straights than in that transition area but in the process of transitioning from a very sluggish rate system to a less than snappy attitude system there is a certain time interval in which you're sort of helpless. I would say that that particular transition -- that blending scheme with these two systems on either side of it is a 9. Or possibly a 10. You know, if you were in bad straights during that, you would hit something. The go-around is a 10. It is unacceptable.

CONFIGURATION B321

PILOT B: 6 Okay, this rate system is too damped. It's too slow in response. And I didn't notice much of a transition on that one. So, it must have been blended fairly slowly into it. Good response in the attitude system. Reset! The rate system is too sluggish. I'll give it about a 6. You can fly but it's too sluggish. The attitude system I liked. The transition I didn't really notice from rate to attitude in the deceleration or the acceleration.

CONFIGURATION B323

PILOT A: 6 — Interesting! Um, I think the sensitivity on that one in the attitude system is a little deficient. It's not down far enough to cause serious problems with controllability. I wish I had more response in close. The problem is that you go from a fairly sensitive system and you get the nose up in that transition and when you start to let the nose down you don't get anywhere near the rate that you've been expecting. I think that's something you can adapt to. But it does cause me some problems in that transition and I don't just slow down. I stop and start backing up. And got to really make a second stage change in my technique. Okay, so what we've got is the attitude system we transition to is just not quite sensitive enough for operations around the ship. I wish it was higher. Also, in comparison to the rates that you get with the initial approach system, it is not the discontinuity -- the blending is very smooth. The problem is that the -- I feel the airplane has changed considerably. Which means you really got to compensate for it. I can get adequate performance but I -- it would take some getting used to. Cooper-Harper 6. The blending is indistinguishable.

CONFIGURATION B343

PILOT A: 4

There it behaves a lot more naturally. I think it's just that the speed is a little illusionary there. It's a flying airplane like out here. It's flying like I think it should. Again. No problems with the transition. The basic attitude system is pretty docile. So I like it. This is still pretty sensitive. It's not horribly useful. Do just about as good a job by eyeball. That's about as good as you're going to get. That final attitude system in here is very docile, very nice to fly. Again no particular problems. It seemed that possible the rate hung on a little longer that time but it didn't really cause any problems. It was not quite as precise in the transition. I give it an upper 4. Again, transition and overall task. It was just not quite as precise during and after the transition. But no particular problem. The blending is a majority of it. You've got a pretty docile final system whenever you arrive at it. The blending sort of dominates.

PILOT B: 7

This rate system again is poorly damped. It just seems like directionally it's poorly damped. Like maybe you need an aileron rudder interconnector, or something? Okay, now I've gone to attitude. Okay, the rate on the attitude is just a little less than -- I'd like to have a little more rate than this. I don't find it objectionable that you changed the system from rate to attitude that quickly like that. I don't much like the rate system because it's not damped enough. I'd give it about a 7. And the attitude system I would give about a 3. The transition I don't either way I don't find is all that difficult.

PILOT C: 4

Oh, I know what the problem with my directional control is -- I'll tell you in a minute. That's -- I've got that one wired, okay. Oops, I think I just took out the hanger. Okay, you can reset it. Okay, I think I see what's going on. I'll make another run before I rate it but for the record I believe we're changing a blending from a turn following on approach type heading control to a lateral translation control in close. And so, initially I've got -- when I bank the airplane it changes heading and in close it appears like when I bank the airplane it goes sideways. And that's very desirable. That's a good thing to have happen. It's just that even initially we're going pretty slow to have a turn following type augmentation. Also, in coming out of hover that time I thought I noticed the transition from attitude to rate. I think I overbanked coming out of hover. Okay, I can feel like I've blended now into the lateral translation type SAS -- laterally. Oops, maybe not. Okay! I can rate that.

Okay, the first thing I would like to do is say on that -- on the first run I made that I rated I probably was not that far up on the learning curve and put kind of a light weighting on those ratings. I might have rated that a little better than I should have. But on this one -- talking mostly about the blending which is what we're most interested in, I think the most dramatic thing is the change in the directional control again which was the same as the last time. And that I did notice in coming out of hover and accelerating that -- there was a fairly abrupt change in my -- the roll rate command. I had a fixed bank angle which suddenly transitioned -- it was kind of a jump. And I think if there was motion I might have felt a sudden increase in roll rate, but from the display I could see a jump, and then a much more rapid turn ensuing as I accelerated away from hover. So I think that is -- that jump in itself wasn't all that big of deal. It would be like a 4 or a 4-1/2 for the blending. As far as the attitude task goes it is still kind of sluggish. I'd like a lot tighter attitude SAS, and I think the gains on approach laterally seem to be way too high. So I would give it like 5-1/2 on the -- just on the basic attitude system on approach, and about a 5-1/2 also on hover. It was kind of loose in hover. It's not so much in the gains. The gains are okay in hover but the response to the system was about a 5-1/2 because it is too sluggish. Incidentally, the blending during the approach is -- I can't even tell when it comes in. So, it is very subtle.

CONFIGURATION B345

PILOT A: 9
Yes. I think I noticed when it made a transition there. I did notice when it made the transition. Oh, wait a minute, no it didn't. I'm going back in and out. -- Oh, now that's something I haven't done before. That could cause a problem on some of these. I'm not really sure what I'm flying, but I don't like it. Oh, let's see that one at least one more time. For some reason it seems a little more sensitive on the initial approach. I might just be getting tired. Oh, we've got ourselves an 8 or a 9 or something like that. That's enough. Let's see it again. Something is happening in there that is sort of disconcerting I guess. Almost a freeze jump. On this one I've got a lot of potential problems. Yes. Controllability is rearing its ugly head. Cooper-Harper is 9. And it is the dynamics -- I think that you've got, I don't know -- very sensitive. A lot of response per inch. But very sluggish to get. That means that if you try and drive it you'll eventually get the response, but then you can't stop it. Very easy to get into problems with that. I don't see too much problem with the transition. The fact is I can't really say what really is occurring. I think I'm noticing a double shift as the discontinuity -- I think I notice a rate change in the response. The sensitivity change in response -- then I notice a discontinuity in attitude. So I don't like that, but particularly the dynamics that I transition into. I don't know if it's the discontinuity between the two systems or if there -- I would have problems with it under any circumstances. But that's a very dangerous system around the ship for me. Cooper-Harper 9. (Referring to the transition) Well, yes, there was some problems in there, too, but I can't really say what it was. You know, there was no abrupt shift or anything like that. It's just that I apparently notice a couple of discontinuities, you know, it's nothing that excites a problem. It's just something that's visually disconcerting.

CONFIGURATION B356

PILOT A: 4 — Okay, the rate system out here on the approach -- build up is slow and the final response is slow. You've got borderline -- well, you know, it's definitely Level 3. You don't have enough rate out here for precision control. You can very easily get into some problems with that kind of system. So sensitivity is the big problem out here and thatis both the dynamic build-up of the rate and the final rate available. It's inadequate. The blending is not totally transparent but it seemed relatively natural. There's no major gain change. (end of tape)

PILOT A: 10 — I seem to have enough rate response. Maybe what I'm seeing out here is the rate as far as degrees/sec/in are good but the dynamic build up is just woefully inadequate. I'm here in the process of transitioning. Control is marginal. You just don't have very much available. You've got the rates that you had with the--the rate buildups that you had with the initial system and the further you get in it seems like the quicker the response gets. This attitude system that you eventually wind up with is not that shabby. Okay. I've seen enough of that one. It's a little hard to sort out on the rate system on the go-around and the approach -- what's the dominant factor and it being so poor. I think it's a combination of the rate of build up and the sensitivity. On the go-around I do notice that it took a lot of aft stick to keep the nose up. So I could tolerate on the go around considerably more sensitivity. I don't have quite as much control problem on the go around as I've seen on some of them. The rate of buildup of the rate is woefully inadequate. It's got to be faster than that. It's borderline unsafe just on the approach. So on the initial approach I give it a 7. You need much more response than that. The transition is unacceptable. The problem with the transition is you drop up out of the rate system, go into an attitude system but you've still got the dynamics that were with the rate system. It's very, very slow to make things happen. As time progresses it gets progressively faster. That means you can never -- about tne time you got doped out what happened the last time you made a stick input, the sensitivity has changed on you. You've got a major controllability problem. If you force the transition in very close I think you'd lose it. I'm going to say that this is totally unacceptable. Give it a 10 for the transition. There's an area in there over which you get this helpless feeling that you don't have any control at all. However, once you have gotten fully

developed attitude system, that attitude system in close is a 3. That's very good. What more can I say? I don't like the rates. The rates are inadequate. The rate of buildup is inadequate. The transition is unacceptable. The retransition to the rate system on the go around is not that bad. However, the sensitivity is unacceptable.

PILOT C: 4,8 Okay. Reset it. I can rate that. That time I did notice something. I was approaching the ship in a fairly nose high attitude and the blend came in and pitched me down very rapidly. I guess that's not a problem as long as this only happens when you're nose high because it only pitches you to a level attitude. It happened to me twice and I think it was on a previous configuration. It happened the first time and I though it was a computer glitch but now I realize it was the blend coming in. So I guess that would be a pilot rating of 4 because you have to do something about it. Although both times it happened for this task and this situation, it wasn't an undesirable thing. Again, the blending on departure seems to be about the same every time. It requires full aft stick. I guess because I'm doing these fairly rapid turning departues, I don't notice any tendancy to roll over. That doesn't seem to be a problem but I do notice that the nose pitches down and I wind up with full aft stick to stop that. That's an 8. So the blending on approach is a 4 and the blending on departure is an 8. I don't know if you're interested in the attitude system but I think the attitude system that we blended to on the approach was a 6. That wasn't too sluggish.

CONFIGURATION B421

PILOT A: 3,7

That one seemed to fly there pretty quickly. Or did it? It took a long time to revert back to a rate system. I'm not sure it ever did. I had some difficulties on the final. I'm still not back in a rate. Now I am. Had a lot of problems coming out of that one. It stays in an attitude or blended attitude system a lot longer than I expected. All of the sudden it seems you've got an abrupt -- you know. It stays there for a long, long time and all of the sudden you've got an abrupt dropoff. Those drops and everything else: it's sort of weird. I pushed the transition in pretty close. Hauled the nose up and could get pretty rambunctious. And I really didn't have any major problems during transition. There's no noticeable discontinuity in control. It seems relatively natural even though I had the nose well up in the air and everything else. I really didn't have any particular problems with control. I put the airplane pretty much where I wanted it. We're back to about a Cooper-Harper 3. Except on the go around. On the go around I don't like that. I'm not sure why I don't. It just sort of hung up there half way in between attitude and rate. You really don't have enough outside cues to judge what is really going on. In other words, I can't tell if I'm translating laterally or not. At the same time, I just don't like the retransition phase of that one. So that particular environment was about a 6 or a 7. I give it a 7.

PILOT C: 6.5,3.5

There are a number of weird things going on about that one that I feel like I'm going in and out of an automatic blend and there are times when my attitude seems extremely sluggish, and then other times it seems fine. And I'm having a problem sorting out what's going on. On one run I approached the deck and I was way too fast and I tried to pull the nose up and it seemed like I just could not get the nose to come up. And then I went and did a second run and I kind of tested the attitude sensitivity at different speeds all the way in and it seemed like -- I could never find that sluggish place again. And so I'm having a hard time sorting out what was really going on. But in general had big problems doing the task. And so I'll just rate the task because I really can't sort out what happened. And the task is -- let's see, a 6-1/2 on the approach and landing. Yes, the close in approach and landing. And coming out of hover I pulled up across the bank angle in and was accelerating out of hover and all of a sudden the bank angle didn't change but the turn rate did. It appeared like. That was my

perception of what happened. And I don't understand that why the turn rates would change but the bank angle doesn't. And I don't know what that was but it wasn't that big of deal. It wasn't any -- so I would call that assuming the simulation is right and all that -- just rating what I saw that would be the -- the acceleration out of hover is a 3-1/2 because it was kind of a strange thing but I didn't have any trouble doing it. And the problem -- the reason it is a 6-1/2 on approach and landing is just because of the pitch dynamics -- that it did not have a good pitch attitude control and couldn't sort out what was going on. But it was both pitch and roll attitudes -- very difficult attaining the pitch and roll attitudes that I wanted and therefore I couldn't get the X and Y positions that I wanted.

CONFIGURATION B423

PILOT A: 7

It's pretty nice. Yes, we've got the same situation that we've seen before. The sensitivity is pretty low. It's light sensitivity. I mean there's enough response. It just doesn't happen fast enough. Keep going in and out of the rate system. Well, you don't get -- a portion of this is not too bad. The problem is that you go onto a sluggish system from one that is pretty brisk. That means that after the transition has occurred you know you now got to make considerable change in your stick strategy. It doesn't -- means that you can go on for a very small input. You've got to go to fairly large ones and try and force the response. You've got enough as far as degrees per inch. The sensitivity itself is good, the rate of build-up is deficient for shipboard use. You could get into trouble with that. It also is compounded by the fact that you're going from one system to another. The transition itself in that case I was noticing some discontinuity in the yaw and on the go-around I noticed a little bit of pitch, too. I'll have to give that a 7.

CONFIGURATION B426

PILOT A: 4,5

As long as I don't have to make any large scale corrections, the initial approach just comes across as just being sort of rock solid. Pretty transparent blending; however, very sluggish attitude system in here. Not overly sluggish. I think it's just the abrupt change from the previous one. I never got totally back into the rate system. Steady as a rock out here but there's not a hell of a lot of response. I'm just sitting here rattling the stick around and there isn't anything happening. If you can't disturb it, it's got to be rock like. Little bit of a flicker as we go between the systems. The transition is relatively natural. It occurs at about the rate and everything else that you'd want. It seems to blend very well. Precision controllability in the attitude system is very good. This is one of the few that I think I can hover. Long, long time to retransition. Okay. What do we got? Sort of inside/outside. The attitude system, I wind up with maybe, a shade sensitive laterally, definitely fine longitudinally with no major problems. I like it. So the attitude system for the hover is very precise. It's a 3. The blending between the two systems is not totally transparent. You just all of the sudden notice a fairly abrupt shift in response or a jump in the display or something and it's a nuisance. I give the blending a 4. On the initial approach, the airplane is flyable on the initial approach. It doesn't have a heck of a lot of response out there though. Both rate and sensitivity. It's certainly adequate for the task. The go around, controllable on the initial transition. It takes a long, long time to blend back into the rate system. Again, all the sudden sort of a bang. You notice there goes the nose and what have. Pretty flyable. I guess I would like that retransition to occur slightly faster. It seems like you're just sitting there holding the stick over for attitude to keep the bank angle and you can hold the stick there forever and a day before it reverts to a rate. So that's compensation. Give that a 5. Not too shabby overall.

CONFIGURATION B431

PILOT A: 3 — All told this is not too shabby. A little tendancy for lateral oscillation in there. It's certainly controllable. Longitudinal P.I.O. developed out here. I ought to be in the transition speed. There it goes - I'm in a rate system. It's relatively -- oh, I see. I'm going back and forth. Sorry about that. Yea. One more time. I get the feeling that rate system is a shade imprecise. I can't quite put my finger on it. Rates, accelerations seem reasonable. It's just a little loose out here and I don't quite know what's causing it; certainly no major problem. I wish it was a little more precise. Very transparent on the blending into the attitude system. Just seems real natural. Bit of a tendancy to get into that longitudinal P.I.O. on the go around again. Dropped back into an attitude system. Okay. My only objection to that configuration is that something's a little puzzling about the rate system. It's a little imprecise and on the go around I have a little tendancy to get into a PIO. Of course, I'm in a fairly ridiculous bank angle. So on the initial approach I've got a slight tendancy to waver around. It's an annoyance rather than a major problem. I would like to have more control. I'm going to call it a Cooper-Harper 5 for the initial approach. The transition is 3. The final approach segment is a 3, the attitude system. The retransition to the rate system is a shade abrupt and I do have some tendancy to oscillate on the go around. That just takes some sorting out. I think with particularly the acceleration cue you wouldn't have quite so much problem. I really don't know what the problem with that rate system is. The sensitivity seems adequate. If anything, I guess I would have to say that the rate buildup particularly in roll is too slow. Pitch seems good. Lateral rate buildup, roll mode time constant, whatever you want to call it, a bit inadequate. Would like to see it accelerate a little bit faster. So the rate system is in the ballpark area of a 5. Overall rating on that task is to get down and land on the ship. It's Level 1. My only objection to it is I wish it flew better up and away.

PILOT C: 2 — There's zero speed. Now I'm going to transition. There's about a 30° bank turn. Zero rate of climb. Okay. All of the sudden the speed jumps up. I didn't see any blend. Just never saw the blend. Okay. You can reset. The blend on approach I never saw and so I guess I have to say that would be 2 since I never saw it. On the departure, it's just total confusion to me.

I've been putting in about a 30° bank and trying to do a general climb and an accelerating departure but didn't seem to be able to do that for some reason. On this last run I finally was able to accelerate and I never saw any blend at all. I don't even want to rate that because I'm not sure what I'm seeing there. The rate system on approach is reasonable. It's about a 4-1/2. Kind of sluggish but reasonable. The attitude system at hover is about a 5; between a 5 and a 6. But the blending on that, just was confused about what I was seeing on those. And again, reiterating, on approach I didn't see anything.

CONFIGURATION B516

PILOT A: 7 Okay, we've got a sort of disconcerting jump there. Dismal discontinuity when it shifts fairly abruptly. My engines are cutting out. Alright, that's disconcerting. I've got full aft stick and I can't bring the nose back up. Okay, let's try it again. It is really an abrupt nose drop. It is probably -- it is disconcerting and probably unrealistic on that. It don't seem to be sufficient power on the go-around. I can't get the nose to come up. When that thing shifts it can be a -- it has a tendency to get into a longitudinal boggle. It is a little disconcerting. I don't think I would like to have that happen in close confines. It is sort of disconcerting right there too as it shifts and it is still the same thing. I've got full half stick -- the nose won't comeup. It is a little disconcerting there. I don't like the control on the go-around at all. In the initial portion, I think if you've got, you know, in a little closer confines when that pitch transitioning occurred, it could cause you some problems. I don't -- well, basically I just don't like that transition is what it amounts to. I got the feeling that you could get into a P.I.O. situation without too much trouble. I had a little hard time picking a number for that one. I can certainly do the job, particularly if I'm aware of it. What I really object to is the dynamics on the go-around. I really can't relate to them. So, that's called a major deficiency. It is a Cooper-Harper 7.

CONFIGURATION B522

PILOT A: 8 — I transitioned out better. Didn't I? What am I in? I'm not really sure what happened back there a couple seconds ago. Okay there's the abrupt jump again about 9 or 10 kts. Did you see that? Okay. That's a distinct nuisance and that abrupt shift like that, I'm in an immediate P.I.O. Wow! The system I'm in is sensitive, fairly well damped and controllable. I don't have any particular problems with it but when you make the abrupt shift like that, my mind doesn't shift gears that quickly and get into that P.I.O. in a hurry. I think we've got ourselves a Level 3 here. That's not going to be acceptable. I'll give it a Cooper-Harper 8. If that caught you at the wrong time, you'd hit the ship. Particularly transition. When you're making a shift like this, the pilot can adapt to either system. When you shift abruptly, if you're using the wrong strategies and P.I.O. city, and that's exactly what happened. Immediately after that transition I got into a fairly violent, lateral P.I.O. but then I stabilized that and made a touchdown and go back and take a look at it. The dynamics aren't horribly sensitive or touchy or anything else. They're very nice once you mentally shift gears.

PILOT C: 5,8 — Now, I don't know what's going on on any of this. Okay, I see. There was an awful lot going on there. I'll start to try to talk through this. I might have to go back and fly it again because there are so many things to remember. On the approach the roll control is way too sensitive. I think I got it. We have a stick sensitivity problem that really -- I guess I would feel comfortable if I had the ability to change the sensitivity because I -- but it seems as long as I keep things very gentle and very slow and don't try to do anything abruptly laterally, I'm okay. But if I put in a lateral -- abrupt lateral stick the roll motions are extreme to that. And so -- and I noticed all the way down to hover I never sensed the change in that. I tested it far out and I tested it in hover and I got, it appeared like the exact same system, and the dynamics are great but the sensitivity appears to be very bad, varied too high. And so we have to give it a -- oh, a 5 and the 5 is strictly because with the -- what appears to be -- looks to me like oversensitivity laterally. Directional control on the approach is -- there is a lot of nose wandering and I can't quite sort out what that is. But as I get in close it appears to me -- my perception is that we always transition to something where the nose doesn't wander that much anymore. And I keep expecting to have a lot of trouble

in close and instead it gets better. So, you blend -- I feel like I'm getting blend to something better and close. So in close I guess, I don't know if you want me to rate directional control separately, but directional control improves to a 4 in close, but the roll control is still up at a 5 because it is too abrupt. And now coming out of hover, it is -- something strange happens and I don't know what it is -- the hose pitches down and all I see is black. And so I end up with full aft stick and I appear to be going up according to my altitude display but I have full aft stick and the nose is somewhere in this black ink bowl and so that's an 8 coming out of hover. And also the system out of hover is -- the gains are way too low. Full back stick hardly pitches the airplane at all. So we transition to a system which is -- first of all gives me a tremendous pitch down and also has too low of gain so I can't recover, so it is an 8 -- accelerating out of transition. The blending coming out of hover is the 8 -- that's what I'm rating an 8 because of that big giant -- I can't totally evaluate what happens but I think I pitch down because I don't have any attitude display left and I put full aft stick in and ultimately I recover and so the 8 I'm giving it is due to that very abrupt pitch down and extremely sluggish stick that I have during and after the blend.

CONFIGURATION B524

PILOT A: 6 That's disconcerting to say the least. Okay, final blending is pretty good on that one. No problems. There is a visual flicker -- it takes a jump on the transition. It's not -- it's disconcerting but it is not something that drives me in an oscillation and I guess the reason that it doesn't is that the dynamics -- the resulting dynamics, final transition into the attitude system, the dynamics I wind up with are docile. I think I could use a higher rate and probably a shade more sensitivity, but it certainly is adequate so I guess I would say the dynamics are down around a 4. The dropping the nose could possibly lead to problems but it is something you can anticipate happening, and adjust for ... and I would have to say that considering that the overall situation, that takes it out of the desired performance and into the adequate performance category. That is something that you would have to again compensate for. So give it a Cooper-Harper 6. The fact that you get a fairly abrupt transition in attitude.

CONFIGURATION B525

PILOT B: 7 Okay, this is damped more but it's -- but there's not enough rate. It's just way too slow. It feels like a bomber. This attitude system is -- it doesn't have enough response. I'd give it about -- something happened! Well, we went over to an attitude system. It seemed like it was fairly quick transition, but I didn't really notice a real sharp change. I seem to be kind of doing a lateral -- a little bit of a lateral P.I.O. here on landing. The rate is just a little slow for the attitude system. That was a -- if you're in the nose up attitude and you go through that transition, that may be a reason for a slow transition into the attitude system. Okay, it looked like a fairly quick transition into the -- okay, you can reset. Well, I'll tell you I just don't -- I don't find -- boy, I'll tell you. I don't know what to tell you about this. Oh, ... I'm trying to sort this thing out in my mind. I don't like the damping on the rate system, all that much. It's too -- oscillates back and forth too much. There's not enough damping. I'm concerned about the decelerating transition. If you did it the way this one is set up right now I'm afraid that it's going to be very -- it's going to cause some problems with somebody coming in nose high. Decelerating which is the way you would normally do it. But the thing is you -- this simulation is not doing what a guy would normally do with a Harrier. With a V/STOL airplane. You normally doing your transition from 90 knots and it's a very rapid deceleration and you're doing your acceleration very rapidly also. And it's tough to tell on these very slow -- see, I can't do a rapid deceleration and a rapid acceleration with what you have here. And it's difficult to tell in my own mind what it would be like if I did a rapid accel or decel. You know, the Harrier can really accelerate from hover to 250 knots very quickly. And if you had a 15-second transition period from attitude to rate, I'm not sure what would happen. Maybe it wouldn't be a problem, maybe it would. Also, your typical decelerating maneuver as you come to the pad or ship -- if you're going too fast and you need to slow down, you normally will raise the nose. And that one time where I did raise the nose and it went from rate to an attitude, the nose dropped down about 10 degrees on me. And that was exactly when I wouldn't want it to do that. So, we may have to look at slower transitions from the rate to the attitude. And we also may have to look at higher transition speeds from rate to attitude. Well, I still don't like the rate system. It's not damped enough. So I would give it about a 7 or an 8.

PILOT A: 6 Seems to be some lag in that response out there and if I get into an oscillation it will sustain itself, I think. Sort of flickered at 19 knots. Pretty solid system in here. It's a little bit sluggish. Full aft stick. A shade on the sluggish side out there in the rate system. Let's see it again. No response. I'm just wiping the cockpit out with the stick. Nothing has happened. Very very sluggish out there in the rate system. There's that jump. That's visually disconcerting. I'm going to have to see this one again and figure out what the heck is going on. Okay, it feels pretty docile out here longitudinally. Laterally I seem to perceive a lag in the response out here in this rate system. Given that you stay somewhere within, you know, within a reason of a small input on the glide slope, the initial system is not too shabby. I do perceive some kind of lag in that lateral response. The jump between the two systems is visually disconcerting and you get about -- oh, one cycle oscillation of a P.I.O. out of trying to compensate for that. This system just has insufficient rate. You've got enough sensitivity in terms of degrees, it just takes -it is wholefully inadequate in getting the rate -- of getting the attitude, getting the acceleration you need for close confines maneuvering. You can do the job certainly. The problem would be that if you inadvertantly got a closure rate developed in close, you know, I'm not -- you just can't stop it, you're going to hit something, or get into an excessive attitude in the recovery. You know, like that. And it is sort of an interesting situation and I now perceive that you have P.I.O. problems due to the sluggish response. I'm going to go around full aft stick again. I don't have what I consider an unreasonable bank attitude. Okay, go-around is unacceptable because I've got full aft stick to prevent myself from flying into the water. And something will have to be done about that. That's the dynamics. It's not the blending schemes -- it is the dynamics. The initial approach, sluggishness laterally -- you can tolerate it as long as you don't have to make rapid, precise corrections. Longitudinally, no real problem. So the initial approach -- I could wish for better sensitivity for sure. You can compensate for it, no big deal. Give the initial approach segment a 5. The transition is very disconcerting initially. You can get yourself into a P.I.O. at least one cycle during that. However, the attitude system is so darned sluggish that initial oscillation doesn't sustain itself. Sensitivity in the attitude system. The rate of build-up is inadequate for shipboard use. Controllability is certainly not a question, so the attitude system that you get into is a Cooper-Harper 7.

The overall rating is -- call it a 6, with the exception of the go-around. The go-around is unacceptable.

CONFIGURATION B526

PILOT A: 9
Better rate response out here. Sensitivity seems better, still maybe should -- well, I guess the sensitivity, oops, how about that! A little underdamped. Quite easy to excite that kind of motion and very hard to dampen. I guess it is lagging in response or something? It doesn't seem to be purely a damping problem. I don't like that worth a darn. Okay, and there goes that abrupt transition. When that nose drops like that you get into a longitudinal P.I.O. Now once the pilot adapts to this system that I'm in here is pretty docile. Very controllable. Very precise. Can't ask for better than that! So this system is 3. Sensitivity on go-around is better. Transition to go-around is better. That one is acceptable. Oh, what I'm seeing out here. The sensitivity and rate build-up aren't too shabby. I don't know, maybe there is a lag in response or something that's causing me to get into an overshoot/undershoot situation and set up an oscillation particularly in bank. Longitudinally, of course, I don't notice it. And there goes that transition -- that transition too early and I guess I'm going to have to see it again. That's visually very very disconcerting. And because of the abrupt change in the sensitivity, I've got mostly a lot of longitudinal P.I.O. until I've had time to sort of rethink what I'm doing. And adapt my control strategy to these dynamics. Okay, but once I do settle down these dynamics are pretty good. The response is good, the controllability is precise. Okay, I do feel like I have control on the go-around. Okay, I've got it sorted out now. Okay, on the approach the sensitivity as far as the rate that you're getting is adequate and that carries over to the departure. It's a very good -- well, not very good -- it's good. You can control it on the departure. The rate buildup is very very sluggish which means you have a tendancy to wait a little bit too long. And then when you take it but you've gone past where you wanted to to which means you get into a lateral P.I.O. Very easily on the approach, particularly if you try and chase the ILS. So, for the approach, you got to stay on top of it and really put in same lead. Controllability really is a question because you get into the sustain P.I.O. motion very easily. So I'll have to rate the approach an 8. The transition, if I transitioned in as close as I would like to I think I would lose it. You really got to really concentrate to maintain control of the airplane during the transition or that abrupt nose down pitch down to a fairly sensitive attitude system you get an immediate longitudinal and if you have any bank angle,

an immediate lateral P.I.O. It's a Cooper-Harper 9. The attitude system for final approach and touch down is about as good as I've seen. I'll give it a Cooper-Harper 3. The transition -- the blending back into the rate system on the go-around. You notice it but it, certainly you can adapt to it at that rate. Everything works out nicely. Same thing carries over on the go-around. You've got adequate rate to control the nose of the airplane. It would be a definite advantage to have that rate build up faster. And because of the large disparity in ratings I'm not going to give you an overall.

PILOT C: 2,8 One problem with this rate system, it doesn't go where you leave it. Like if I pitch down, it pitches back up. It acts like somewhere between 40 and 15 knots. I got half of each. Oh, yea. Big transient there. I think it's a reasonably good attitude system this time but just that the stick sensitivity is too high. It's a good attitude system but the stick sensitivity is too high on this one. Okay. I can rate that. Okay. The blend coming into hover, again, didn't notice it. The only thing that I can say is that on the second of that sequence I didn't fly the task. I just flew level and it seemed like I have half attitude and half rate which looked more like a very sluggish attitude system and the speed ratio between 15 and 30 knots is the perception I had. . . .This isn't required on the approach and so the kind of sluggish attitude dynamics end results in that intermediate stage are not that noticeable. The attitude system in hover that time was quite a bit different than last time. It was a much higher frequency system and I think it would be a good system except that the stick sensitivity seemed too high. But the damping and the frequency seemed excellent. I tended to overcontrol it though because of that stick sensitivity problem and then accelerating out of hover, again we had kind of a nose down transient at the blend and very abrupt which seemed to be kind of okay at first. Then about two or three, maybe five seconds, later then the nose came to a very large pitch down. So it's an initial abrupt transient followed by a very large more slowly but rapidly building up pitch down and that's unacceptable because again I had full back stick in to keep the nose from pitching down. I picked it up as an 8. It's a little more benign than last time but still definitely you wouldn't want to have that operationally.

CONFIGURATION B534

PILOT A: 7

Okay, I've got a little bit of a jump there. I've got a two-stage thing. I've initial noticeable change in the response and then I got an attitude jump. Oh, now, I like this system. Oops. Yes, now the sensitivities and response to this attitude system are pretty good -- pretty good. It's probably disconcerting when it takes that fairly rapid jump from -- in attitude. Let's see, the harmony between the two systems is excellent. The sensitivity before and after the shift are good and the sensitivity I've got here in this attitude system is good -- and the rates and sensitivity are appropriate to the task. Okay, the system that transitioned into is good. If it wasn't for the discontinuity during that transition -- that fairly abrupt attitude shift -- this would be a really good system. That very objectionable one when it takes that very abrupt longitudinal transient. Now you've got to assume it would take the transient. And then the other axis it -- I had disturbed at the time. There's not much you can do about it either. You can't anticipate or anything like that. It's just a fairly abrupt transition. Now that might cause some difficulties if you were in very close to the ship and that nose popped back down on you. I do like the sensitivities on this, but I'm going to have to say that -- Cooper-Harper 7 because of the transition.

APPENDIX C

PILOT DATA

Very briefly, the pilots' background were as follows:

<u>Pilot A:</u> Ex-military A-4 pilot, current in flight aerobatic aircraft, some V/STOL and helicopter time. Current assignment as flying qualities engineer.

<u>Pilot B:</u> MCAIR test pilot, F-15 and AV-8 V/STOL experience.

<u>Pilot C:</u> Systems Technology, Inc. research and engineering pilot, extensive CTOL, V/STOL and helicopter experience.

APPENDIX D

AIRWAKE MODEL

A simplified airwake model from NADC 77143-30 Vol. III was used. The simplified equations and assumptions are presented herein.

Assumptions:

ψ_{s_o} = 0°, ship reference heading with respect to North

V_s = 15 kt, ship speed

ψ_{WOD} = 0°, wind over deck direction

ψ_{WIND} = 0°, ambient wind direction with respect to ship heading

V_{WIND} = 10 kt, ambient wind velocity

ψ_S = 0°, ship yaw angle in body axis which related orientation of ship body axes to ship inertial axis.

1. <u>Ship c.g. and Touchdown Point Locations in Inertial Axes</u> (Figure D-1).

1. $X_{S_I} = X_S + \int_0^t V_S dt$

2. $Y_{S_I} = Y_S$

3. $Z_{S_I} = Z_S$

4. $X_{TD_I} = X_{S_I} + \Delta X_{TD}\cos\theta_s + \Delta Y_{TD}\sin\theta_s\sin\phi_s + \Delta Z_{TD}\sin\theta_s\cos\phi_s$

5. $Y_{TD_I} = Y_{s_I} + \Delta Y_{TD}\cos\phi_s + (-\Delta Z_{TD})\sin\phi_s$

6. $Z_{TD_I} = Z_{S_I} + \Delta X_{TD}(-\sin\theta_s) + \Delta Y_{TD}\cos\theta_s\sin\phi_s + \Delta Z_{TD}\cos\theta_s\cos\phi$

$\Delta X_{TD} = -117.7\text{ft} \qquad \Delta Y_{TD} = 0 \qquad \Delta Z_{TD} = -29.1\text{ft}$

Inputs:

X_S, Y_S, Z_S

θ_S, ψ_S, ϕ_S - ship motions as defined by ship motion equations. Units are ft for X_S, Y_S, Z_S and deg for θ_S, ψ_S, ϕ_S.

Outputs:

X_{TD_I}, Y_{TD_I}, Z_{TD_I} - touchdown point location along X, Y, and Z axes, respectively, of a north-oriented earth-fixed inertial system (ft)

2. Aircraft c. g. Location Relative to Touchdown Point In Ship Wind Axes (Figure D1)

1. $X_{A/S_W} = (X_{A_I} - X_{TD_I})$

2. $Y_{A/S_W} = (Y_{A_I} - Y_{TD_I})$

3. $Z_{A/S_W} = (Z_{A_I} - Z_{TD_I})$

Inputs:

X_{TD_I}, Y_{TD_I}, Z_{TD_I} - touchdown point location along X, Y, and Z axes, respectively, of a north-oriented earth-fixed inertial system (ft)

X_{A_I}, Y_{A_I}, Z_{A_I} - aircraft c. g. coordinates in the same north-oriented earth-fixed inertial system (ft)

Output:

X_{A/S_W}, Y_{A/S_W}, Z_{A/S_W} - describe the aircraft c. g. location in an inertial axis system whose origin is at the touchdownpoint, X axis points into the relative wind over deck, Z axis aligns with the local gravity vector, and Y axis forms a right hand orthogonal system with the X and Z axes (feet).

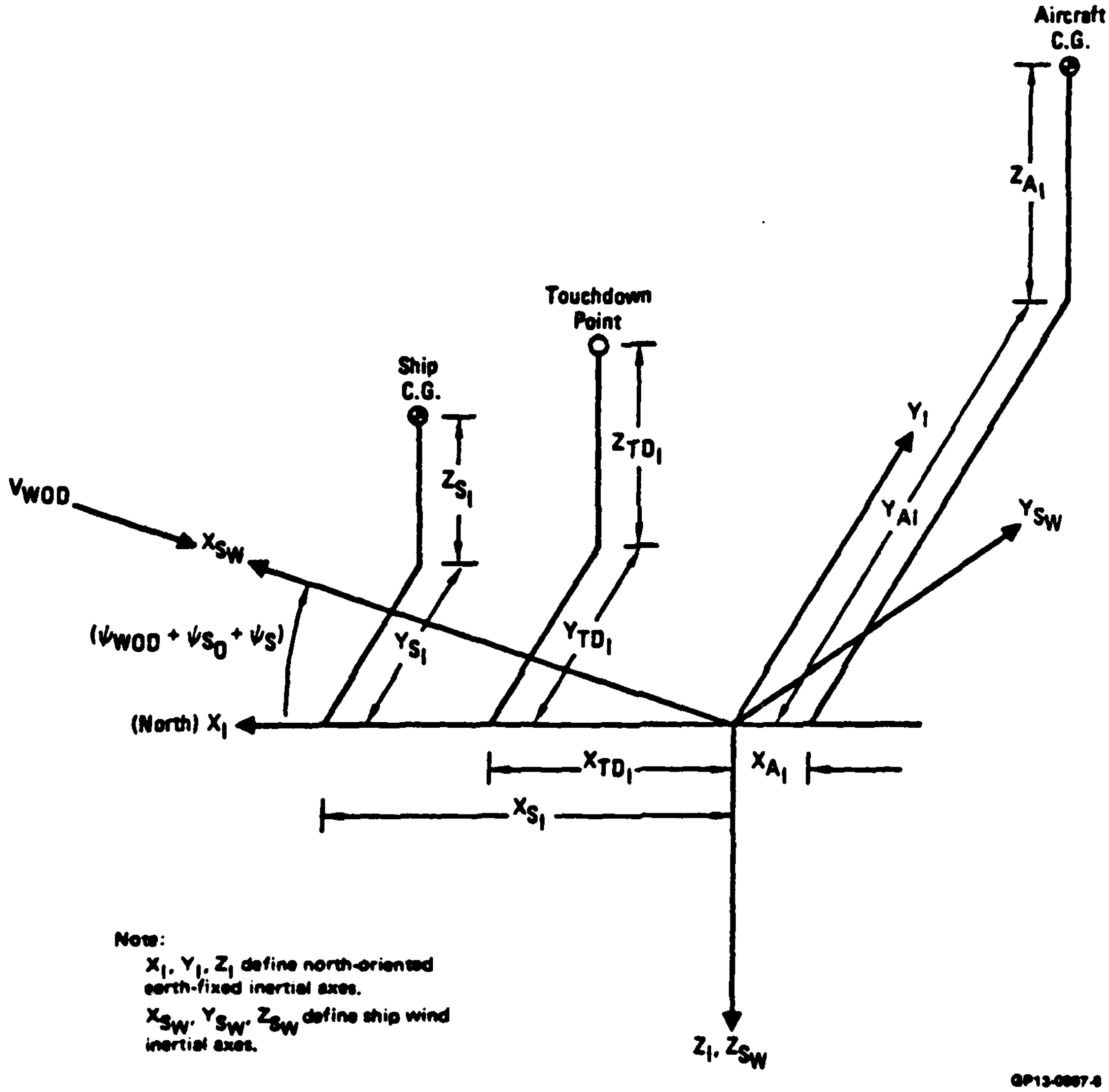

Figure D1. Aircraft C.G. Location Relative to Touchdown Point in Ship Wind Axes

3. Strouhal Scaling Relations

1. $X_{1052} = \left(\frac{w_{1052}}{w_{963}}\right) X_{A/S_W}$

2. $Y_{1052} = \left(\frac{w_{1052}}{w_{963}}\right) Y_{A/S_W}$

3. $Z_{1052} = \left(\frac{w_{1052}}{w_{963}}\right) Z_{A/S_W}$

4. $$\omega_{n_{x_o}} = \begin{cases} 8.17 & \omega_{n_{x_o}} \geq 8.17 \\ 8.17 + .0346X_{1052} & 1.58 < \omega_{n_{x_o}} < 8.17 \\ 1.58 & \omega_{n_{x_o}} \leq 1.58 \end{cases}$$

5. $$\omega_{n_{y_o}} = \begin{cases} 10.41 & \omega_{n_{y_o}} \geq 10.41 \\ 10.41 + .0389X_{1052} & 3.00 < \omega_{n_{y_o}} < 10.41 \\ 3.00 & \omega_{n_{y_o}} \leq 3.00 \end{cases}$$

6. $$\omega_{n_{z_o}} = \begin{cases} 10.00 & \omega_{n_{z_o}} \geq 10.00 \\ 10.00 + .0374X_{1052} & 2.88 < \omega_{n_{z_o}} < 10.00 \\ 2.88 & \omega_{n_{z_o}} \leq 2.88 \end{cases}$$

7. $\omega_{nx963} = \omega_{n_{x_o}} \left(\frac{V_{WOD}}{76}\right) \left(\frac{w_{1052}}{w_{963}}\right)$

8. $\omega_{ny963} = \omega_{n_{y_o}} \left(\frac{V_{WOD}}{76}\right) \left(\frac{w_{1052}}{w_{963}}\right)$

9. $\omega_{nz963} = \omega_{n_{z_o}} \left(\frac{V_{WOD}}{76}\right) \left(\frac{w_{1052}}{w_{963}}\right)$

Constants:

$\omega_{1052}/\omega_{963} = 46.75/55 = 0.85$

V_{WOD} = variable but is constant for any single approach (ft/sec)

Inputs:

$X_{A/S_w}, Y_{A/S_w}, Z_{A/S_w}$ - describe the aircraft cg location in the ship wind axis system (ft)

Outputs:

$X_{1052}, Y_{1052}, Z_{1052}$ - Strouhal equivalents to X_{A/S_w}, Y_{A/S_w}, and Z_{A/S_w} and are used to enter the airwake data base. (ft)

$\omega_{n_{X_{963}}}, \omega_{n_{Y_{963}}}, \omega_{n_{Z_{963}}}$ - break frequencies of white noise filters which generate random airwake components (rad/sec)

4. Shaping Function Logic for Data Base Extrapolation to Free Stream Conditions

Shaping Logic for ψ_{WOD} = 0 deg (figure D2)

1. $$X_{BD_1} = \begin{cases} \ell_{TD} & X_{BD_1} \geq \ell_{TD} \\ \dfrac{\ell_{TD}}{\left(\dfrac{W_{1052}}{2} - 200\right)} (|Y_{1052}| - 200) & 0 < X_{TD_1} < \ell_{TD} \\ 0 & X_{BD_1} \leq 0 \end{cases}$$

2. $$F_{X_1} = \begin{cases} -1 & X_{1052} \geq X_{BD_1} \\ \cos \dfrac{\pi X_{1052}}{X_{BD_1}} & 0 < X_{1052} < X_{BD_1} \\ +1 & X_{1052} \leq 0 \end{cases}$$

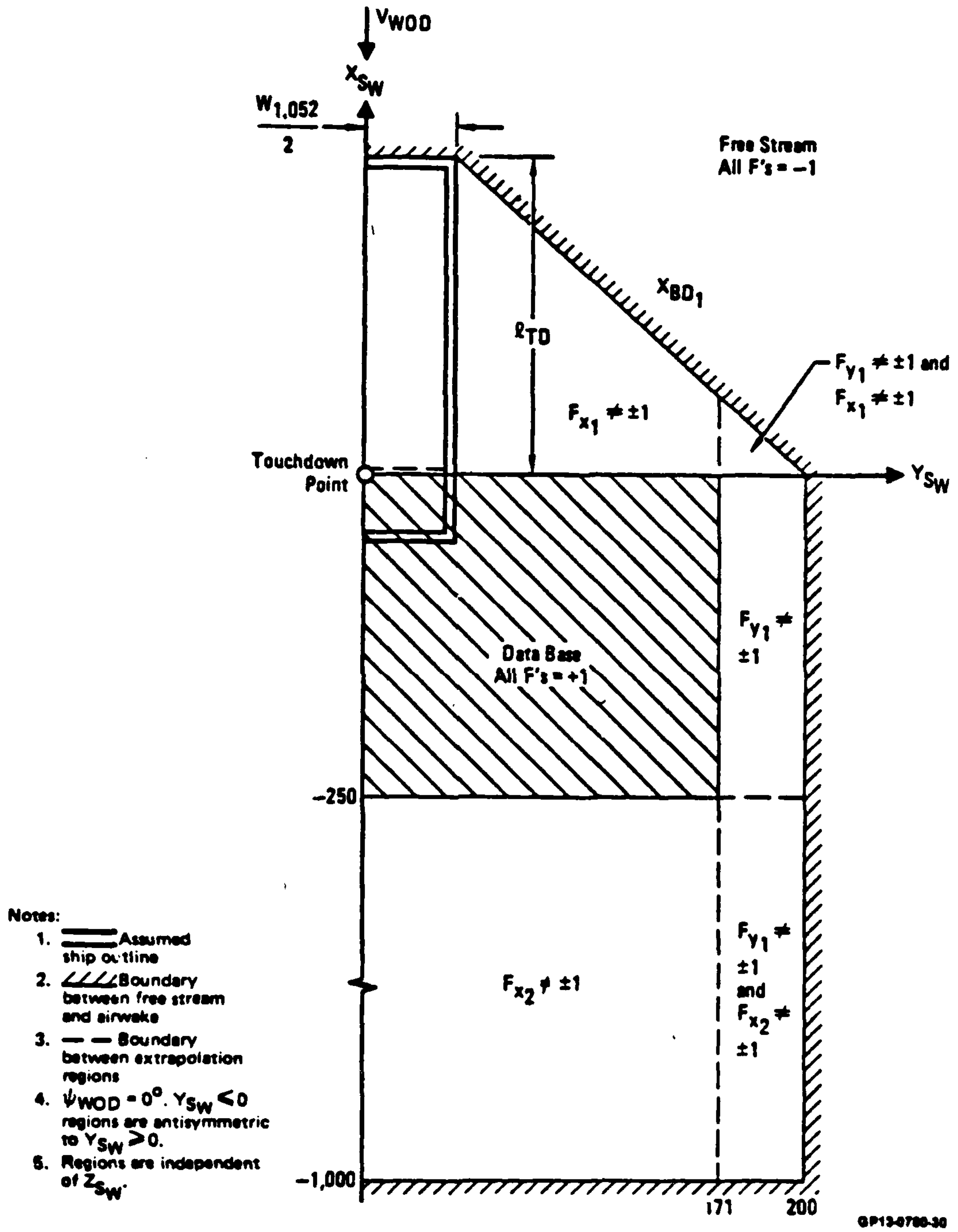

Figure D2. Definition of Data Base Extrapolation Boundaries in the $X_{SW} - Y_{SW}$ Plane for ψ_{WOD} = 0 Deg

$$3.\quad F_{x_2} = \begin{cases} -1 & X_{1052} \le -1000 \\ \cos \dfrac{(X_{1052} + 250)\,\pi}{-750} & -250 > X_{1052} > -1000 \\ +1 & X_{1052} \ge -250 \end{cases}$$

$$4.\quad F_{y_1} = \begin{cases} -1 & |Y_{1052}| \ge 200 \\ \cos \dfrac{\pi(|Y_{1052}| - 171)}{-29} & 171 < |Y_{1052}| < 200 \\ +1 & |Y_{1052}| \le 171 \end{cases}$$

$$5.\quad F_{z_1} = \begin{cases} -1 & Z_{1052} \le -100 \\ \cos \dfrac{\pi(Z_{1052} + 44.58)}{-55.42} & -44.58 > Z_{1052} > -100 \\ +1 & Z_{1052} \ge -44.58 \end{cases}$$

$$6.\quad F_1 = \frac{1}{16} \cdot (1 + F_{x_1})\,(1 + F_{x_2})\,(1 + F_{y_1})\,(1 + F_{z_1})$$

Constants:

$$\ell_{TD} = \ell_{TD_{963}} \left(\frac{w_{1052}}{w_{953}}\right) = 422.3 \left(\frac{46.75}{55}\right) = 359 \text{ ft}$$

$$w_{1052} = 46.75 \text{ ft}$$

Inputs:

X_{1052}, Y_{1052}, Z_{1052} - Strouhal equivalents to X_{A/S_W}, Y_{A/S_W}, and Z_{A/S_W} and are used to enter the airwake data base (ft)

Outputs:

F_1 - shaping function for data base outputs

5. Airwake Statistics Generation

1. $$Z_{TAB} = \begin{cases} -14.58 & Z_{1052} > -14.58 \\ Z_{1052} & -44.58 \le Z_{1052} \le -14.58 \\ -44.58 & Z_{1052} < -44.58 \end{cases}$$

2. $$X_{TAB} = \begin{cases} 0 & X_{1052} > 0 \\ -X_{1052} & -250 \le X_{1052} \le 0 \\ 250 & X_{1052} < -250 \end{cases}$$

3. $$Y_{10\ddot{5}2} = \begin{cases} -Y_{1052} & \psi_{WOD} > 0 \\ |Y_{1052}| & \psi_{WOD} = 0 \\ Y_{1052} & \psi_{WOD} < 0 \end{cases}$$

4. $$Y_{TAB} = \begin{cases} -18.75 & Y_{10\ddot{5}2} \le -18.75 \\ Y_{10\ddot{5}2} & -18.75 < Y_{10\ddot{5}2} < 171 \\ 171 & Y_{10\ddot{5}2} \ge 171 \end{cases}$$

5. $$\bar{V}_{X_{A_W}} = \left[59.1 - \bar{V}_X \quad (X_{TAB}, Y_{TAB}, Z_{TAB})\right] \left(\frac{V_{WOD}}{59.1}\right) \quad F_1$$

6. $$\bar{V}_{Y_{A_W}} = \bar{V}_Y \quad (X_{TAB}, Y_{TAB}, Z_{TAB}) \left(\frac{V_{WOD}}{59.1}\right) \quad F_1$$

7. $$\bar{V}_{Z_{A_W}} = \bar{V}_Z \quad (X_{TAB}, Y_{TAB}, Z_{TAB}) \left(\frac{V_{WOD}}{59.1}\right) \quad F_1$$

8. $$\sigma V_X = \sigma V_X \quad (X_{TAB}, Y_{TAB}, Z_{TAB}) \left(\frac{V_{WOD}}{59.1}\right) \quad F_1$$

9. $$\sigma V_Y = \sigma V_Y \quad (X_{TAB}, Y_{TAB}, Z_{TAB}) \left(\frac{V_{WOD}}{59.1}\right) \quad F_1$$

10. $$\sigma V_Z = \sigma V_Z \quad (X_{TAB}, Y_{TAB}, Z_{TAB}) \left(\frac{V_{WOD}}{59.1}\right) \quad F_1$$

Constants:

V_{WOD} - variable but constant for any single approach (ft/sec)

Table Data:

Only the tables for $\psi_{WOD} = 0$ deg are presented.

$\bar{V}_x = \bar{V}_x (X_{TAB}, Y_{TAB}, Z_{TAB})$ for V_{WOD} = 35 kt, ψ_{WOD} = 0 deg

a) Z_{TAB} = -14.58 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	25.41	30.94	38.11	37.81	42.79
18.75	31.68	35.96	42.63	42.41	42.56
54	46.23	47.81	51.77	51.53	51.49
104	50.36	50.27	56.48	56.44	56.56
171	56.05	56.92	56.14	56.42	56.27

b) Z_{TAB} = -25.00 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	31.52	35.46	40.67	41.44	44.54
18.75	40.26	42.67	46.99	47.07	46.70
54	49.00	49.40	54.68	54.23	53.52
104	55.43	56.30	55.36	55.49	55.56
171	57.84	58.74	57.87	58.13	58.03

c) Z_{TAB} = -44.58 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	39.05	40.40	42.47	42.61	45.25
18.75	49.06	50.54	49.57	48.18	47.78
54	56.57	56.21	56.32	56.24	55.88
104	55.50	55.48	54.90	54.90	54.80
171	58.56	58.78	58.70	58.85	58.63

$\overline{V}_y = \overline{V}_y (X_{TAB}, Y_{TAB}, Z_{TAB})$ for $V_{WOD} = 35$ kt, $\psi_{WOD} = 0$ deg

a) $Z_{TAB} = -14.58$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	-0.78	-1.25	-0.14	1.34	0.68
18.75	-4.35	-4.40	-4.28	-3.83	-2.03
54	-2.55	-2.75	-1.21	-1.99	-0.91
104	-0.15	-0.41	1.44	1.33	0.65
171	2.13	1.71	2.79	2.10	2.07

b) $Z_{TAB} = -25.00$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	1.16	0.91	3.90	-0.85	-0.97
18.75	-6.09	-4.41	-3.34	-3.07	-0.57
54	-2.54	-2.04	-1.69	-1.72	-1.47
104	-2.16	-3.08	-1.77	-1.70	-2.21
171	1.77	1.40	2.84	2.19	2.03

c) $Z_{TAB} = -44.58$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	-2.68	-2.68	-1.68	-1.53	-3.40
18.75	-2.85	-2.31	-0.054	-0.70	0.63
54	-1.81	-1.83	0.84	0.22	0.26
104	-0.42	-0.28	1.57	0.85	0.94
171	0.59	0.45	1.43	0.80	0.84

$\overline{V}_z = \overline{V}_z\,(X_{TAB}, Y_{TAB}, Z_{TAB})$ for V_{WOD} = 35 kt, ψ_{WOD} = 0 deg

a) Z_{TAB} = -14.58 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	5.59	4.42	5.35	3.78	0.73
18.75	3.07	0.55	1.04	1.12	-1.94
54	-2.15	-2.80	-1.31	-1.25	-1.88
104	-1.61	-1.96	-0.29	-0.71	-0.93
171	-0.40	-0.44	-0.66	-0.69	-1.16

b) Z_{TAB} = -25.00 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	1.65	1.15	0.10	1.08	-0.83
18.75	2.16	1.74	1.41	2.65	-0.22
54	-1.16	-1.96	0.24	-0.57	-2.37
104	-1.54	-0.25	-0.84	-1.28	-1.16
171	-0.85	-0.67	-0.87	-1.10	-1.46

c) Z_{TAB} = -44.58 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	-5.76	-3.90	-2.84	-3.61	-4.02
18.75	1.72	1.70	1.70	0.49	0.32
54	-2.31	-1.72	-2.15	-1.93	-3.95
104	-4.43	-3.57	-5.44	-5.32	-5.30
171	-2.07	-1.54	-2.05	-1.73	-2.07

$\sigma_{v_x} = \sigma_{v_x}(X_{TAB}, Y_{TAB}, Z_{TAB})$ for V_{WOD} = 35 kt, ψ_{WOD} = 0 deg

a) Z_{TAB} = -14.58 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	6.82	5.43	5.99	5.70	5.41
18.75	5.92	5.67	6.62	5.64	5.21
54	4.44	3.44	4.86	4.15	3.88
104	0.69	0.64	0.58	0.78	0.51
171	0.36	0.44	0.39	0.41	0.39

b) Z_{TAB} = -25.00 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	5.22	5.35	5.71	5.38	5.10
18.75	5.60	5.26	5.84	5.32	4.84
54	2.50	1.97	2.26	2.30	2.74
104	1.83	1.57	1.70	1.76	1.45
171	0.47	0.49	0.48	0.46	0.46

c) Z_{TAB} = -44.58 ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	6.77	6.35	5.41	5.55	3.70
18.75	6.40	6.65	6.43	4.83	4.55
54	0.86	0.86	0.76	0.89	0.99
104	0.39	0.38	0.52	0.63	0.57
171	0.37	0.49	0.37	0.40	0.45

$\sigma_{v_y} = \sigma_{v_y} (X_{TAB}, Y_{TAB}, Z_{TAB})$ for $V_{WOD} = 35$ kt, $\psi_{WOD} = 0$ deg

a) $Z_{TAB} = -14.58$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	7.90	9.69	9.95	9.38	8.44
18.75	6.63	5.85	5.63	5.81	5.45
54	5.22	3.15	3.55	3.54	3.59
104	0.99	0.98	1.05	1.34	0.78
171	0.92	0.66	0.61	0.68	0.72

b) $Z_{TAB} = -25.00$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	8.93	8.44	9.67	7.60	6.19
18.75	6.05	6.96	6.51	6.05	6.18
54	2.59	2.06	2.31	2.27	2.75
104	2.62	2.46	2.50	2.43	2.12
171	0.71	0.56	0.79	0.62	0.53

c) $Z_{TAB} = -44.58$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	10.91	8.80	8.25	7.68	5.67
18.75	7.74	6.59	7.82	6.81	5.14
54	1.18	1.37	1.02	1.01	1.32
104	0.61	0.62	1.14	1.19	1.05
171	0.86	0.87	0.87	0.62	0.83

$\sigma_{v_z} = \sigma_{v_z}(X_{TAB}, Y_{TAB}, Z_{TAB})$ for $V_{WOD} = 35$ kt, $\psi_{WOD} = 0$ deg

a) $Z_{TAB} = -14.58$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	7.58	7.73	7.83	5.97	5.81
18.75	7.77	7.47	6.76	6.71	6.02
54	4.92	3.88	4.87	4.50	3.70
104	0.97	0.85	0.92	1.20	0.81
171	0.60	0.68	0.59	0.66	0.54

b) $Z_{TAB} = -25.00$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	7.16	6.91	6.10	6.60	5.08
18.75	7.64	6.08	7.08	5.56	4.66
54	3.78	2.83	2.38	2.62	2.64
104	1.04	0.82	0.69	1.14	0.82
171	0.73	0.58	0.62	0.59	0.56

c) $Z_{TAB} = -44.58$ ft

Y_{TAB} \ X_{TAB}	0	37	90	125	250
0	8.30	8.33	6.46	6.07	5.52
18.75	6.80	6.24	6.36	5.66	4.37
54	1.11	1.10	0.83	1.17	1.43
104	0.58	0.77	0.97	0.97	0.82
171	0.58	0.99	0.59	0.65	0.70

<u>Inputs:</u>

X_{1052}, Y_{1052}, Z_{1052} - Strouhal equivalents to X_{A/S_W}, Y_{A/S_W}, and Z_{A/S_W} and are used to enter the airwake data base (ft)

F_1 - shaping function for data base outputs

<u>Outputs:</u>

$\bar{V}_{x_{AW}}$, $\bar{V}_{y_{AW}}$, $\bar{V}_{z_{AW}}$ - mean airwake velocities at the aircraft c.g. in the ship wind axes (ft/sec)

σ_{v_x}, σ_{v_y}, σ_{v_z} - standard deviations of the airwake velocities (ft/sec)

% Random Airwake Velocity Component Generation

1. $\dot{v}_{X_R} = -\omega_{nX_{963}} v_{X_R} + \sigma_{V_X} \sqrt{2\omega_{nX_{963}}} \; N_X$

2. $\dot{v}_{Y_R} = -\omega_{nY_{963}} v_{Y_R} + \sigma_{V_Y} \sqrt{2\omega_{nY_{963}}} \; N_Y$

3. $\dot{v}_{Z_R} = -\omega_{nZ_{963}} v_{Z_R} + \sigma_{V_Z} \sqrt{2\omega_{nZ_{963}}} \; N_Z$

4. $v_{X_R} = \int \dot{v}_{X_R} \, dt$

5. $v_{Y_R} = \int \dot{v}_{Y_R} \, dt$

6. $v_{Z_R} = \int \dot{v}_{Z_R} \, dt$

Inputs:

$w_{n_{x963}}$, $w_{n_{y963}}$, $w_{n_{z963}}$ - break frequencies of white noise filters which generate random airwake components (rad/sec)

N_X, N_Y, N_Z - independent "white" noise sources for driving the first order filters which produce the random velocity componets.

Outputs:

V_{X_R}, V_{Y_R}, V_{Z_R} - random components of the airwake velocities (ft/sec)

6. Airwake Velocities in Inertial Axes

1. $V_{X_{AW}} = (\bar{V}_{X_{AW}} + V_{X_R}) - V_{WIND} = (\bar{V}_{X_{AW}} + V_{X_R}) - 16.89$

2. $V_{Y_{AW}} = (\bar{V}_{Y_{AW}} + V_{Y_R})$

3. $V_{Z_{AW}} = (\bar{V}_{Z} + V_{Z_R})$

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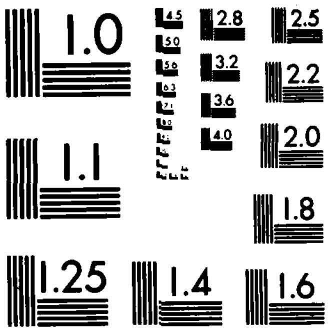

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